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RADIANT HEAT TRANSMITTED BY FLAMES.

By CAPTAIN JOHN ERICSSON.

From "Engineering."

The temperature produced by the radiation of flames, is a subject of far greater importance than generally supposed. Some distinguished physicists imagine that the radiant power of flames is considerably less than that of incandescent solid substances, contending that it is impossible to ascertain the temperature of the sun because the radiant heat transmitted is the result of the radiation of the incandescent gases of the photosphere. The accompanying illustration, Fig. 1, represents an apparatus originally constructed to demonstrate the unsoundness of this assumption, and to prove that the radiant power of flame is not less than that of incandescent solid bodies. In a practical point of view, an exact knowledge of the temperature produced by the radiant heat transmitted by flames, is of great importance, as it furnishes means of measuring, with desirable precision, temperatures which the nature of the materials at our command renders it impossible to ascertain by direct contact. It was shown in the article on Solar Heat, published in "Engineering," December 30, 1870, that the intensities of circular radiators of *different* size, imparting equal temperature at *equal* distance from the radiating surface, are inversely as the squares of the sines of half of the subtended angles, that is, the angles formed by the axes of the circular radiant surfaces and the heat rays projected from the circumferences to the substance receiving the radiant heat, in the prolongation of the axes. It will be evident on reflection that, agreeably to this proposition, it is possible to determine the temperature of an inaccessible circular radiator *without knowing its size or distance.* The method of measuring temperature, which we are going to consider, depending solely on the correctness of the paradoxical proposition just stated, it will be necessary to subject the latter to some test of a practical nature before we proceed to examine in detail the device by which the radiant intensity, transmitted by a flame, is rendered subservient in determining its temperature. It will be seen by referring to the description of the solar pyrometer, contained in the article before referred to, that the radiant heat transmitted from a circular radiator of known size to the bulb of a thermometer applied at a known distance, within a vacuum, has been ascertained with critical nicety. It has been shown that, with an angle of 16 deg. 8 min. subtended by the axis of the radiator and the heat rays projected from the circumference towards the bulb, the temperature of the radiator will be 12.91 times that indicated by the thermometer receiving the radiant heat. This fixed relation between the angle subtended and the temperature transmitted is evidently of the utmost importance. In connection

with the fact already noticed, that the intensities of radiators of different size are inversely as the squares of the sines of the subtended angles, it enables us to apply the proposed practical test in support of the assertion, that the temperature of an inaccessible radiator may be determined without ascertaining its size or distance. Astronomy furnishes the information that the angle subtended by a line drawn from the circumference of the sun, and a line drawn from its centre towards the earth when the latter is in aphelion, is very nearly 15 min. 46 sec. The corresponding angle subtended by the radiator of the solar pyrometer and its axis being 16 deg. 8 min., it will be found by an easy calculation that the square of the sine of the angle subtended by the sun, is to the square of the corresponding sine of the radiator of the pyrometer as 1:3685.71. The experiments with this instrument having established the fact before stated, that the intensity of the radiating surface is 12.91 times greater than the temperature transmitted to the focal thermometer, it will be readily perceived that in order to raise the focal temperature to 84.84 deg. the temperature of the radiator must be $84.84 \times 12.91 = 1095.28$ deg. And if we suppose its diameter to be reduced to such an extent that it subtends an angle of only 15 min. 46 sec., like that subtended by the sun, it will be obvious that its temperature, owing to the small radiating surface, must be vastly increased to transmit a temperature of 84.84 deg. to the focal thermometer. The foregoing explanation having demonstrated that the increase of temperature required under the stated conditions, will be inversely as the sines of the subtended angles, viz., 3685.71: 1, it will be seen that the temperature of the diminished radiator must be 3685.71×1095.28 deg. $= 4{,}036{,}884$ deg. in order to transmit the stated temperature of 84.84 deg. to the focal thermometer. It scarcely needs explanation that the temperature last mentioned has been selected as a basis of our calculations, on the ground that the intensity of solar radiation is 84.84 deg. at the boundary of the atmosphere when the earth is in aphelion, in which position, it will be recollected, the before-mentioned angle—15 min. 46 sec.—is subtended. Consequently, the temperature of the sun, deduced from the data furnished by the results of the experiments with the solar pyrometer, without reference to the sun's distance or size, will be 4,036,884 deg. Now, computations based on the sun's distance and diameter, in accordance with the theory that the temperature produced by radiant heat is inversely as the areas over which the rays are dispersed, in connection with the ascertained intensity of solar radiation at the boundary of the terrestrial atmosphere, show that the temperature of the sun at the surface of the photosphere somewhat exceeds 4,035,500 deg. (See demonstration, vol. iv. p. 125) Considering this close agreement between the results arrived at by methods totally different, and considering the severity of the test applied, that of comparing the effect of radiant heat at a distance of 18 in., to that acting through a space exceeding 90,000,000 miles, we cannot question the soundness of the doctrine enunciated at the commencement of our discourse, nor question the practicability of measuring the temperatures of distant inaccessible bodies without knowing their size or distance. The important fact should not be overlooked that our demonstration relates only to the temperature of *circular* radiators. But it will be shown hereafter that the temperature of radiators of an irregular form, whether consisting of incandescent metallic bodies or flames, may also be ascertained, irrespective of the distance and size of the radiating surface, provided that distance be short.

Before examining the adopted expedients of measuring the temperature transmitted by the radiation of flames, it will be necessary to consider their composition. Professor Draper, who has closely investigated the subject, states that the flame of a lamp consists of three principal divisions: First. A central nucleus which is not luminous, and consists of combustible vapor. Secondly. An intermediate portion, the true flame, arising from the reaction of the air and the combustible vapor, and being composed of a succesion of superposed shells, the interior being red, the exterior violet, and the intervening ones colored in the proper order of refrangibility; the cause of this difference of color being the declining activity with which the combustion goes on deeper and deeper in the flame. As to temperature, Professor Draper considers that the inner red shell cannot be less than 977 deg. Fahr., and the exterior violet one probably more than

2,500 deg. Fahr. Thirdly. An envelope consisting of the products of combustion, exterior to the true flame, shining simply as an incandescent body, and its light for the most part overpowered by the brighter portion within. Apart from the difficulty of giving to such a flame as the one described the form necessary to render exact measurement of its radiant power possible, the result would be of little value owing to the want of homogeneity and uniformity of temperature. Our investigation, therefore, will be confined to what may be termed solid flames of uniform temperature throughout the mass, such, for instance, as the flames of reverberatory furnaces and cupolas surrounded by walls that prevent the action of the exterior atmosphere. Evidently, if we can ascertain what intensity of flame is indispensable to fuse a metal, we at the same time ascertain the temperature of the fused metal itself. It will be reserved for a future occasion, to present a delineation and description of an instrument by means of which the temperature of such flames may be measured for practical purposes; our present object is simply that of answering the theoretical question, Is the temperature transmitted by solid flames equal to, or less than that transmitted by incandescent metallic bodies? The reader will bear in mind that this investigation was originally undertaken to refute the assertion of certain savants, that the temperature of the sun cannot be ascertained because the radiant power of incandescent gases is less than that of incandescent solid matter.

Fig. 1 represents a conical furnace provided with a grate applied at the contracted lower portion, admitting of a free passage of the air over the entire surface. A capacious chamber is formed under the grate, into which air is forced by an ordinary Sturtevant centrifugal blower. The internal portion of the furnace is contracted towards the top, as shown in Fig. 2, terminating with a square opening, over which is placed a square trunk corresponding exactly with the said opening. The furnace being charged with combustibles that readily ignite, it will be evident that a moderate speed of the blower will, soon after ignition, fill the square trunk with a solid flame of perfectly uniform temperature throughout, contact with the exterior atmosphere being wholly prevented, while the air which supports the combustion is subdivided almost infinitely, and uniformly dispersed, through the mass of burning fuel. A chimney of very large section, equal to that of the contracted part of the furnace, being applied above the square trunk, any tendency to pressure and accumulation in the same will be effectually prevented. A solid flame of uniform temperature having thus been obtained, its radiant power has been ascertained by the following device. A conical vessel open at the large end, surrounded with a water jacket of cylindrical form, shown in Fig. 2, is secured to the square trunk, a circular opening being formed in the side of the latter, corresponding with the open end of the conical vessel. Referring to Fig. 2, it will be seen that a perforated diaphragm (composed of polished silver) is introduced near the small end of the conical vessel. A thermometer is applied near the circular perforation of the diaphragm, the bulb being placed exactly in the centre line of the vessel. An opening, surrounded with a short conical tube, covered with a piece of mica, affords a view of the interior of the conical vessel. The water-jacket is supplied from the street main, a constant stream being kept up during experiments. The application of a chimney of large diameter above the square flame-trunk, and the covering of the short conical tube with mica, as stated, in order to prevent any current of heated air or gas through the conical vessel, have contributed to secure the desired result. A disk of flame of uniform brightness, the color varying with the speed of the blower, has been successfully produced. Respecting the experiments which have been instituted, it may be briefly stated that, when the blower is worked at the most advantageous speed for producing a flame of maximum brightness, the thermometer exposed to its radiant heat indicates 282 deg., while the temperature of the water circulating through the external casing is 73 deg. Hence, the heat transmitted to the enclosed thermometer by the radiation of the flame produces an augmentation of temperature of 282—73=209 deg. Fahr. The angle subtended by the centre line of the conical vessel and lines drawn from the circumference of the flame-disk to the bulb of the thermometer, being 16 deg. 8 min., precisely as in the solar pyrometer, we know that its temperature must be 12.91 times greater than that indicated by the inclosed

thermometer. Accordingly, the temperature of the flame passing from the furnace through the square trunk into the chimney will be $12.91 \times 209 = 2{,}698$ deg. Fahr., a result corresponding very nearly with ordinary pyrometer indications; a fact, however, of little importance in view of the uncertainty of such indications. It will be supposed that the stated high temperature of the flame must at once destroy the square trunk. Such, however, is not the case, from the reason that the trunk is made of plate-iron only 1-16 in. thick, the radiation of which is so rapid that the gases composing the flame—these gases being slow conductors—cannot communicate the heat as fast as it is carried off by radiation. The top of the furnace at the point where the flame is concentrated and conducted into the square trunk, being exposed to intense heat, is lined with fire-clay. It should be observed that the apparatus is exposed to a high temperature only while the blower is in operation, the motion being stopped as soon as the internal thermometer reaches maximum indication.

It will be noticed by those who have attentively studied the article on radiant heat published in a former number of this magazine, that, unless the radiant surface forms a spherical concavity, the focus of which coincides with the centre of the bulb of the recording thermometer, the indication will not be exact. The flame-disk being *circular*, this objection is overcome by removing the thermometer from the face of the flame to such a distance, that the mean length of the heat rays transmitted to the bulb corresponds with the radius of a concave radiator of the same diameter as the flame-disk, subtending the before-named angle of 16 deg. 8 min. As already mentioned, the consideration of the *practical application* of the principle developed by the apparatus represented by our illustration, almost self-evident to constructive minds, has been reserved for another occasion. In the meantime engineers will be interested to learn that instruments are being constructed by means of which the temperature of metals, of any temperature, may be measured with positive accuracy by simply ascertaining their radiant power at a convenient but unknown distance.

AN UNWRITTEN CHAPTER OF THE METALLURGY OF IRON.

By ROBERT MALLET.

From "The Engineer."

Probably the oldest pieces of iron forged by the hand of man, which have reached our time, may be the sickle blade found by Belzoni, under the base of a granite sphinx at Karnak; the sheet, or possibly blade, of some sort found by Colonel Howard Vyse, embedded in the masonry of the Great Pyramid, and revealed after a blast of which Mr. St. John V. Day, C. E., has read an interesting account this year before the Philosophical Society of Glasgow; and the larger portion of a cross-cut saw, exhumed by Mr. Layard at Nimrood, all of which are now in the British Museum. Assuming the Pyramid to have been in existence 2,000 years before our era, and that the metallic arts must have had some centuries of incubation and improvement in Egypt previously, this blade, embedded in the huge ashlar work of the Pyramid, brings back the working of iron or steel, and the abundance of either of these bodies, such that common tools were made of them in Egypt, to an epoch from 4,000 to 4,500 years before the present time. Though Egypt be still supposed the country in which the earliest historical monuments, and historical or *quasi* historical records of our race have been found, it neither follows nor seems probable that its technical arts originated and were perfected wholly within its own borders; the cradle of its arts as well as of its inhabitants, was somewhere else, and everything points for those to some still remoter East.

Without attempting to follow link by link the chain of evidence—such as it is, and at many points obscure—we may venture to believe that the knowledge of working in iron reached Egypt from the East, and had, if not its origin, yet its earliest practice in the high lands of Central Asia; and, if so, allowing time for its migration westwards and southwards, iron working was known in Asia 5,000, or per-

haps 5,500 years ago. Nor does even this reach or give any indication of the actual origin of the art, or of the discovery that must have preceded it. Some Tubal Cain there must have been, who first found that the brittle and unglistening piece of heavy red or brown stone, or compact clay, could, by heating and hammering, be brought to the state of a much heavier black, hard, and tough mass, extensible only by blows while hot, and having, when broken or ground upon a stone, whiteness and metallic lustre. But there may have been—indeed, it is almost certain there were—many Tubal Cains, *i. e.*, many such independent discoverers, differing in time, and living at widely apart points of our globe.

The rare use of iron amongst the Esquimaux and some negro tribes of Western Africa, obtained from reputed meteoric iron, though perhaps very ancient, cannot on good grounds be supposed, as it has been, to have suggested the working in iron to all the rest of the world.

Suppose the fact known, the next step is too great. What link is there to connect the bright mottled meteoric iron with any red or brown stone, little differing from every clod the uncultured man trode upon? The true origin of iron working from its ores must have been in a country rich in timber fuel, with red or brown hematites abundantly showing themselves, and peopled by a race endowed with the higher intellectual faculties, and already advanced beyond the savage state.

All those conditions existed at periods remote beyond tradition in Central Asia; indeed, they exist at the present moment at many centres north and south of the Himalayas. But they also, in all probability, existed at equally and possibly still more remote epochs in those vast regions of far Eastern Asia that we roughly comprehend under the name of China.

The pre-historic archæology of this part of the earth yet remains to be explored. China must have had its period of troglodite caves and stone instruments, but with a horizon in time almost unimaginably higher than those ages of which the *vestigia* have been discovered in Europe; for China presents evidences of a civilization, distinctive, earlier, longer, and greater than that of any other Asiatic or European nation.

Iron-making may have been independently discovered in Central Asia, but it may also, and with more probability, have travelled there from the ancient peoples of the remotest east of that continent; and if so, its earliest traceable epoch, again allowing time for migration, would mount to an antiquity equal to or exceeding that of the whole vulgar chronology of mankind, which fixes the age of the world at about 6,000 years.

If these views be admitted, the most ancient fragments of iron or steel extant are aged but about half of the vast period that has elapsed since iron, with more or less probability of proof, has been known to man as a manufacture; and how much higher still in time may have been the discovery of the metal itself by some primordial Tubal Cain, we have no present means of even conjecturing.

The object of this article, however, is not to discuss the origin of iron-working, except in so far as it is needed to indicate the amazing periods during which it has been practised in Asia, with a view to pointing out, by one or two striking examples, how extremely imperfect is our knowledge of the phases through which this ancient Oriental metallurgy has passed; that it has not been always, as is the common belief, what we see it now in India, and that within the comparatively short period of a few centuries past, working in iron was carried on in India upon a scale so stupendous as to rival the productions of our largest steam-hammer forges in the Europe of to-day.

It is strange that of the iron metallurgy of Asia, the mother land of all the arts, of India, the country where, more than 20 centuries ago, King Porus presented to Alexander the Great *apacka*, or wrought bar of Damascene steel, just as Homer's Achilles offered for a prize at the funeral games of Patroclus a like valued mass; whence the Greeks obtained the like material for their "wonder-working sword blades" (*θαυμασια ζίφη*); where steel dies were employed for coinage when our own ancestors were naked savages; of China, whence *cast-iron* hollow vessels now reach us of a combined magnitude and thinness, that we have not yet been able to imitate or even to imagine the process by which they are cast, and razor steel said to surpass all European steel in temper and durability of edge,—less is known than of the iron working of

any other parts of the more or less civilized world; yet such is the fact.

Central Asia, and even China, as yet are nearly *terræ incognitæ*; but India south of the Himalayas has been more or less open to European observation for centuries, and has been in our own power for more than one. How little is known of the working of iron in China may be gathered from the bald and imperfect accounts of it given (pp. 52-58) by MM. Stanislas Julien, Mem. Inst., and Paul Champion, Preparateur au Conserv. des Arts et Metiers, in their work on the "Technical Arts of the Chinese Empire," published in Paris in 1869; the first named author having a reputation as one of the first Chinese scholars in Europe, and the second being a competent metallurgist and technologist. Yet China possesses the knowledge of working in *fluid cast iron*, as well as in wrought iron and steel—the first being, at the present day, at least, commonly reputed to be unknown in India, where wrought iron is made direct from the ore, and steel also.

A *résumé* of the methods of working iron in India, which is probably the best that exists in English, has been given by Dr. Percy, in his "Metallurgy of Iron," but it is all comprised in about twenty pages, and though a good deal of scattered information on the subject may be found elsewhere, it probably would add but little of importance to what he has collected.

Dr. Percy, however, passes by the historical side of the subject altogether, or contents himself with the following paragraph as to it, with which his statements open (p. 254): "The Hindoos appear to have carried on the *direct process* (*i. e.*, making *wrought iron* direct, without it passing through the *indirect* stage of cast iron) from time immemorial, as we may infer from the large accumulations of slag which occur in various localities in India; and as it is scarcely possible to imagine anything more rude than their appliances, or anything more diminutive than their scale of operations, it would seem that they have not made any substantial progress in the art, at least in many districts. Their furnaces are frequently not larger than a chimney pot, and hours of incessant toil are sometimes required to produce a few pounds weight of iron." This may be taken as a rough account of the present state of iron working in India. But without going back so far as "time immemorial," the facts now to be adduced prove it to be a very incomplete, or rather inaccurate view of the history of iron working in India only a few centuries back.

Within the cincture of the ancient mosque of the Kutub, situate near Delhi (so named from the celebrated and grandly lofty Kutub minar forming part of the mosque), and not far from the principal gate, exists a wrought-iron pillar. This wrought-iron pillar is as large as the screw shaft of one of our first class steamships, and a forging of the same size would be deemed a piece of first class work for any one of our great steam hammer forges in Europe, and yet it is more than 1,000 years old, and may be as much as 1,500. Its form is either that of a conic frustrum or of some curvilinear spindle, giving it a very slight swell towards its mid-height. The capital consists of an elaborate Indian design, the whole of which good observers deem to have been carved by the chisel out of the solid iron. The shaft to near the present ground level is beautifully smooth and true, and presents the character of having been "swaged," or, if not, "sledge planished" to its finished form. The lower part for 3 or 4 ft. above the present ground, and below it, is rough and but carelessly rounded; there appear to be some rather large cavities in this part of the shaft. This pillar has been known to Europeans for many years. The earliest printed notice of it which the writer has seen is in the "Journal of the Asiatic Society of Bengal," vol. vii., p. 659, *et seq.*, being part of a memoir "On Lithographs and Translations of Inscriptions," taken in Ectype, by Captain T. S. Burt, Engineer. A much more extended account may be found in vol. xxxiii. after p. 612 of the supplement to the same journal, forming part of the Report of the Archæological Surveyor to the Government of India for the season of 1862-63.

The dimensions of the pillar may be approximated from paint marks in a vertical line placed upon it, at distances of 12 in. apart, which have transferred themselves to the photograph. The following are those given by the Archæological Surveyor, above referred to, at p. 34, etc.: "The total height above ground is 22 ft.,

that of the capital 3½ ft., and that of the rough part near the ground the same. But its depth under ground is considerably greater than its height above ground, as a recent excavation was carried down to 26 ft. without reaching the foundation on which the pillar rests. The whole length of the iron pillar is, therefore, upwards of 48 ft., but how much more is not known, although it must be considerable, as the pillar is said not to be loosened by the excavations. I think, therefore, it is highly probable that the whole length is not less than 60 ft. The lower diameter of the shaft is 16.4 in. and the upper diameter is 12.05 in., the diminution being 0.29 in. per foot. The pillar contains about 80 cubic feet of metal, and weighs upwards of 17 tons."

There may be some doubt as to the correctness of the great depth underground assigned here, but the dimensions above ground seem reliable, and are from actual measurement. The total weight assigned seems somewhat in excess, even on this author's assumption as to length. An inscription of 6 lines exists on the pillar itself, about half-way of its height, which records in fact all that is known as to its history. Of this Captain Burt gives the following account:—"The principal inscription on the Delhi iron pillar is in Sanscrit, the character that form of Nagari which has been assigned to the 3d or 4th century of the Christian era. * * * * The curves of the letters being squared off, perhaps on account of their having been *punched* upon the surface of the iron shaft with a short *cheni* (punch) of steel and a hammer, as the actual engraving of them would have been a work of considerable labor." The inscription itself is of the most disappointing sort—its purport is merely to record that "a prince, whom nobody ever heard of before, of the name of Dhava, erected it in commemoration of his victorious prowess; thst he was of the Vaishnair (Hindoo) faith, occupied the throne he had acquired (at Hastinapura ?) for many years, and seems to have died before the monument was completed; as no royal ancestry is mentioned he was probably an usurper." A transcript of this inscription, showing the squared letters, exists in vol. vii. of the "Journal of Royal Asiatic Society," and in vol. xxxiii. of same a copious mass of archæology and mythology bearing upon it, which those interested in those branches of knowledge can consult. Our business with the pillar is exclusively as a metallurgic monument.

The data of its production is, as we have seen, fixed by the inscription as the 3d or 4th century, A. D. Its form and chief dimensions are before us. Now what is the material of the pillar, for upon this depends the nature of the processes by which it must have been made; is it of cast iron or of wrought iron? As to this the evidence is as yet not absolutely decisive.

The Archæological Surveyor, in his report above referred to, appears to have thought it to be cast iron; he says, "The Delhi pillar is a solid shaft of *mixed metal.* * * * * * There are flaws in many parts which show that the casting is imperfect, but when we consider the extreme difficulty of manufacturing a pillar of such vast dimensions, our wonder will not be diminished by knowing that the casting of the bar is defective,"—p. 34. What this writer means by mixed metal it is hard to conjecture; he obviously had no knowledge of practical metallurgy, and his opinion must pass for what it may. Captain Burt, who appears to have had some such practical knowledge, obviously deems the pillar to be of wrought or forged iron, and supports that opinion by his ingenious and practical remarks as to the punching on it of the inscription. This latter view receives the following corroborations: the writer's accomplished and accurate friend, Mr. James Ferguson, Archt., F. R. S., who has carefully examined the pillar, is clearly of opinion that it is of forged iron. A fragment of it has been recently sent to England, and the writer is informed, on, he believes, good authority, that Dr. Percy has heated and drawn out upon the anvil a portion of it, and considers it to be forged iron. This test, probably all that so small a specimen admitted of, is not absolutely conclusive, as Dr. Percy himself would no doubt admit, for some cast irons, especially those made from hematites with charcoal fuel, admit of being heated and at once forged and drawn out hot into a sort of wrought iron. The photograph, as examined with the lens by the writer, presents to the practical eye several minute characteristics which incline him to believe it to be forged and not cast iron.

There will be seen clearly in the photograph—and also, though less so, in the

engraving—the mark of the graze of a heavy round shot on one side, at about mid-height of the pillar; and so far as can be decided by examination of the photograph, the shaft is slightly cracked across, the widest part of the crack being at the side opposite to the graze mark. The blow, then, was just not enough to break completely the pillar by its own inertia, when thus suddenly bent beyond the limit of elasticity. Did we know the *vis viva* of the striking mass, and the density and exact dimensions of the pillar, it would be possible to calculate approximately the cohesion per square inch of the outside film of the shaft at this crack, assuming it really to exist; but wanting such data, and judging by tact or experience only, the writer is of opinion that if of British cast iron the pillar would have been broken completely off by the blow of a heavy shot.

The existence of a doubt as to the material of this pillar, one of the most marvellous metallic monuments in the world, shows with how little completeness it has yet been examined, and how entirely ignorant those who have described this pillar have been of the importance in elucidating the ancient working of iron in India of an exact metallurgical examination of its material. Let us hope this will forthwith be remedied—by cutting from the pillar (below the surface, it may be) and sending home a piece sufficiently large and long, not only for chemical investigation, but for experimental determination of its extensibility and cohesion per sq. in.; for physical and chemical examination together can alone determine with certainty whether it be of oriental cast iron or of wrought, *i. e.*, forged iron.

But meanwhile let us take the alternative suppositions, and see to what they will lead us. At the present day the prevalent belief is probably the correct one, that the production of or working in cast iron is unknown to native Indian workmen south of the Himalayas; and, unless made under European direction, a pig of cast iron of 100 lbs. weight could probably not be found in India. Yet how little is systematically known about the matter may be gathered from a recent notice ("Times," December 4, 1871) of some remarkable travels in 1868 in Central Asia by a native emissary of the Indian Government. "At Faizabad, the capital of Budukshan, a town a mile and-a-half in length and half-a-mile in breadth, along the banks of the Kokcha river, he found the inhabitants skilful in smelting iron, and they send cast-iron pots, pans, ornamental lamps, etc., to the market."

Assuming that in past time cast iron was known and worked in India, there is yet no reason to suppose that the furnaces in which it was melted could have been much larger than the little cupola furnaces, with blast from native bellows, which are now in use for making wrought iron direct. The very largest of these native furnaces appear to be those of Burmah ("Percy," p. 271, etc.), which by draught only produce about 90 lbs. of iron at each operation. It would have required between 300 and 400 such furnaces, working on cast iron, all got ready to tap and tapped at the same moment, to run a casting of 17 tons—an operation which any practical founder would admit to be impracticable with such apparatus, even in the hands of trained European workmen. Nor must it be imagined that the product of the existing little Indian cupolas, working on the direct process, is ever fluid enough to be tapped or run from the furnace. Were it so it might be conceivable that this pillar had been cast, and yet was of a crude wrought iron, or of a metal intermediate to cast and wrought iron.

Mr. R. W. Bingham, magistrate at Chynepore Shahabad, district of Bengal, in his report on iron-making, published in the official descriptive catalogue of the Indian articles exhibited in 1862 at London (4to, Calcutta, 1862), says as to that region of Bengal: "The metal never runs liquid from the furnace, but falls to the bottom below the blast pipe, from whence it is taken in a flaming mass by a pair of iron tongs, and which is hammered on a large stone, or on a rough iron anvil, into a double wedged-shaped pig," etc. This seems to describe the existing process of iron making of the present day, not only in Bengal, but all over British India, differing only in the size of the "bloom" or pig made, which is most commonly but 9 lbs. or 10 lbs., but in Burmah seems to reach its maximum size, viz., about 90 lbs., or rather less than one-third the weight of "bloom" produced in one operation by the existing Catalan furnaces in Europe,

viz., about 140 kilogrammes ("Pelouze and Fremy," vol. iii., p. 228).

Are we then to conclude that this pillar was cast, in the absence of any evidence in support of that view—indeed, in face of whatever evidence we possess bearing on it—merely because we cannot conceive any other way in which it might have been made in India? If so, it follows, that between the fourth century, A. D., and the present day, the whole art of smelting iron in India has been changed, and that the indirect, or European method has been lost, and with it the knowledge of working in cast iron itself been also lost. Such a view is untenable, for vessels, or other objects of ancient cast iron, must, in that case, occasionally be found, which does not seem to be the case.

We are thus obliged to consider that this pillar is not a casting, but is a huge forging in native Indian or some other Asiatic-made wrought iron, and if so, the question arises, how was it forged? We have no evidence that "blooms" of more than 90 lbs. or 100 lbs. each, were ever made by Indian methods; these would be too small to build up singly into a bar of 16 in. diameter. It is, however, conceivable that such little "billets" as were procurable from such blooms might be welded up into bars, and these bars made into a faggot, out of which such a bar, by sufficient means for bringing it to a welding heat, and for then hammering it, might be welded into a cylindrical bar such as that of this iron pillar.

Now, the limit to the size of a faggot that can be welded with given means of *heating* it, is found to be when the mass is so great in proportion to the power of the furnace that the exterior of the mass, where the heat is being applied, oxidates and melts away, owing to the slowness of heating; and hence long continuance of exposure to the heat, as fast as piece after piece is laid on to make up for the waste. This limit has been reached before now even in our best reverberatory forge furnaces; it actually was touched upon at Liverpool, in forging the Mersey Company's great 13-in. gun. Unless, therefore, the iron-working of India between the 3d and 4th century, A.D., possessed air furnaces and lofty stalks, or blowing apparatus of some sort upon a scale now unknown, and indeed not conceivable in any form of native apparatus, we may confidently affirm that no faggot to form a welded bar of 16 in. in diameter could have been by any possibility brought to the welding heat at all, or without such waste as to prevent its ever being forged.

If we pass from the heating of such a bar to the forging of it, our difficulties are still greater. The limit in size of *hand-forged* work in Europe was about reached in the production, in days gone by, of the heaviest "best bower" anchor of a ship of the line. The largest section of the anchor shank, when welded to the arms, was about 8 in. or perhaps 9 in. across, and the welding was effected by the blows of 24 "strikers," trained to strike in time, and swinging 14 lb. to 18 lb. sledges. The shower of blows dealt for some minutes' spell, upon the mass of iron of this large section, produced a very insignificant effect, so that both the faggoting and the welding of such anchors were often very defective, and the strikers having to stand close in a ring, within the short distance for swinging the sledge from the glowing iron, were greatly scorched by its radiated heat, and some with fine skins were unfitted for the work. Hereabouts, then, the limit to hand-forging was reached, both as to the power of the hand sledge to act upon the mass of iron, and as respected the power of the men to endure the heat radiated from the glowing iron at the short distance from it limited by the length of the handle of a sledge when swinging. Now the section of the shank of a "best bower" of 8 in. or 9 in. diameter, is, to that of the Delhi iron pillar, about as 64 to 201, or the latter would radiate from its heated extremity more than thrice as much heat, and an equal length more than thrice as great a mass to be dealt with by the sledge hammer, as in the case of the anchor. We may, therefore, affirm that even in European hands a bar of wrought-iron of 16 in. diameter could not be welded up by hand labor with the sledge. The latter would produce no adequate impression—least of all in the comparatively feeble hands of Asiatics; and human skin and muscles could not withstand, at 5 ft. or 6 ft. off, the intolerable glare and scorching of such a mass heated to the welding point. How, then, was this Delhi pillar forged in India, even assuming that some means for heating it existed? Forging by power in some form, of course, suggests itself,

but upon what source of power can we even speculate? Human muscles, and the "bullock walk" by which the water skins, or "bheesties," are drawn up from the wells or tanks, appear the only present sources of power in India. The water-wheel, or *noria*, for *raising* water by the application of such animal power, is common; but the production of power by the *descent* of water on a wheel seems never to have been known in India, where, indeed, except in the hill districts, no "falls" for water-power exist. The windmill, though said to have been known in Persia from some very remote period, has never been seen in India; and, it need scarcely be said, steam-power is out of the question.

It is barely imaginable that some form of falling tup hammer raised by men acting on ropes, after the manner of the old ringing engine for pile driving, may have been employed, or some rude form of tup or tilt hammer moved by bullocks acting on a walking wheel; and it is for Indian archæologists to discover if there be any records or traditions of such appliances, without which the methods by which this huge pillar was forged must remain inexplicable. The pillar itself stands before us, so far, a metallurgic enigma; if it stood alone, and were this great ancient forging in wrought-iron alone known to exist in India, we might pass it by, content to suppose it too isolated an instance on which to found any conclusions as to the iron metallurgy of that country in former ages; but, although little noticed, and apparently quite unknown to our European writers on iron metallurgy, this pillar does not stand alone.

Not to lay any stress on the probable existence in India of other iron pillars, as affirmed to the writer by an accurate Indian officer well acquainted with the country, the following facts are recorded by Mr. James Fergusson, in his "Illustrations of Ancient Architecture in Hindostan," fol., London, 1848, p. 28, and Plate III.

In the Temple of Kanaruc, or Black Pagoda, in the Madras Presidency, "the walls of the mantapa or porch (which is about 60 ft. square inside) are about 10 ft. in thickness, and the depth of the doorways is, consequently, 20 ft., and their lintels are supported by large iron beams of about 1 ft. section, laid across from side to side. The roof is formed after the usual bracket fashion of the Hindus, each course projecting beyond the other, so as to give (from the inside) the appearance of inverted stairs * * * * At about half the height, where its dimensions narrow to about 20 ft., a false roof has been thrown across, the remains of which now lie heaped up as they fell on the floor of the apartment. Among them may still be remarked several beams of wrought-iron about 21 ft. in length and 8 in. section, and a great many blocks of stone, 15 ft. and 16 ft. long (and they were probably broken in their fall), and of a section of 6 ft. by 2 ft. or 3 ft." Here then we have employed as mere building material wrought-iron bars of 8 in. square and 21 ft. long. Mr. Fergusson views this temple as having been built between A. D. 1236 and 1241.

In another temple examined and described by Mr. Fergusson—that of Mahavellipore, standing alone on a solitary rock of granite projecting into the very surf on the coast, near Madras—and the date of which he refers to the 10th or 11th century A. D., but deems may be as late as the 13th or 14th century, and described in his great work as above, p. 57, and Plate XVIII.—he informs me there are empty sockets for beams, like those just noticed; the beams, he justly argues, must have been of iron, as the sockets show a scantling, which would have been if in timber perfectly useless under the load carried.

It is highly probable that at Kanaruc the ceiling beams thrust themselves out of their sockets by alternate expansion and contraction, and so brought down the "false roof," as the filling above is called; but the place affords a bad foundation, and is said to be subject to earthquakes. However, our business with these iron beams is simply as metallurgic monuments. Here, then, we have the fact that at Delhi, in the north, and at Madras, in the far south of India, massive forgings exist, such as all Asia, so far as we know, could not produce at the present day, and of a size rivalling those upon which Europe to-day prides itself. The earliest of these dates from the 3d or 4th century, and the latest from the 11th to the 14th century of our era. With such an interval of time as 900 or 1,000 years, and such a diffusion in space as from north to south of India, it seems impossible not to con-

clude that the evidence of these monuments attests the existence in India for that long period of a great iron manufacture, well established, and with a relative cheapness and certainty of product that admitted of the use of iron as a material for public monuments and as a building material in sacred edifices, and that this manufacture was extinct, and the art and methods lost, long before any modern European occupation of India. So that far from Indian iron working having been the same feeble thing we see it to-day from time immemorial, it was once a great and flourishing craft, and extended over parts of the entire Indian peninsula.

Nothing heretofore brought to light in the history of metallurgy seems more striking, to the reason as well as the imagination, than this fact: that from the remote time when Hengist was ruling in Kent, and Cerdic landing to plunder our barbarous ancestors in Sussex, down to that of our Third Henry, while all Europe was in the worst darkness and confusion of the Middle Ages—when the largest and best forging producible in Christendom was an ax or a sword blade—these ancient peoples of India, the forerunners of those now so enfeebled and degraded, possessed a great iron manufacture, whose products Europe even half a century ago could not have equalled.

Yet, these conclusions rest on no new facts, but on the colligation of old ones, by the light of practical knowledge. Indian archæologists and writers have long known of the existence of these iron monuments of an ancient and lost art in India, but their importance has, the writer believes, not before been recognized as bearing on ancient Oriental metallurgy. The reason of this is that those who have examined the monuments of India, however scholarly and able in many ways, have not been metallurgists, and have had no practical knowledge of iron-working. The ancient, and, indeed, the existing technology at large of India—still more of Asia at large remains almost unexplored and undescribed, and whenever it shall be examined, analyzed, and described by really competent men—and such have never yet been commissioned with the task—results even more strange, and perhaps of more importance, historical and practical, than these deducible from the Delhi iron pillar, will, no doubt, come to light.

Since the foregoing was in type a notice has appeared in "Les Mondes" (tome xxvi., Dec. 1871), by M. Sévoz, an engineer of mines, resident in Japan, of the iron working districts of that country, which may throw some light on the conjectural modes by which these great forgings may have been effected by human power in those remote ages in India. In reference to the mode of iron-working in the mining province of Ykouno, M. Sévoz says, "The treatment employed is a sort of imperfect Catalan method * * * * but what distinguishes the Japanese method from that of (Depart.) Ariége is that they treat at once 16,000 kilos. of ore, and produce an enormously long pig of 1,300 kilos. which is broken up under a huge hammer, constructed after the style of a pile-driving ram, to which motion is given by a walking wheel of 11.5 metres diameter, acted upon (montée) by men. One can see that potent blows may thus be given, but their frequency and regularity do not seem such as thus to admit of a forging being produced, even if the means for heating a mass as huge as those referred to were capable of being guessed at.

THE WEIGHT OF RAILS.

By LOUIS NICKERSON.

From "The Railway Register."

A prevailing idea seems naturally to exist that great weight in a railroad bar is necessary to its economical wear. This is shown by the usual remark, when saving of the rail is noted—from the use of the Fairlie engine—in regard to the narrow gauge claims, or when steel is substituted for iron, "that it is better for economy's sake not to reduce the section, but rather to rely upon greater longevity than upon saving in first cost for gain." It may be true. But, after much thought on the subject, I have come to a totally different conclusion, and as each addition-

al ounce of iron above the necessary quantity is so much money locked away from the use of companies, a discussion of the question which should prove that this, like all other natural phenomena, has its maximum and minimum points, cannot fail to be useful. Useful at any rate in drawing attention to the subject and thereby eliciting the truth.

The rail, unlike the other structural appurtenances of a railroad, has two separate uses, which call for two separate modes of treatment. First, in its character as a beam to convey the wheel from one cross tie to another. Secondly, its character as a road-bed to withstand the tearing and abrading influences, which result from the dragging of heavy loads over it. For the first case we have the general shearing stress, which from its depth may be disregarded, and the bending moment, which may easily be derived from calculation. Then, arranging the tranverse section so as to oppose the shearing stress, which tends to tear the side of the head along the line of the web, and otherwise place the iron in the best position for sustaining a known moving load, and moreover knowing the quality of the material exactly, the whole necessary size and weight as a beam may be deduced from formula, with a fair allowance for security.

But, beyond this, we must regard the rail in its capacity as a road surface, gather the facts and phenomena concerning its abrasion, and especially as regards its being torn into shreds and ribbons by some laminating cause, and inquire whether any additional mass of iron could be used to prevent it. It is evident that this laminating is governed by the amount of pressure brought to bear upon the upper surface, and we may first consider whether by an increase of material this surface could be made greater. It would seem not, for it having been already determined by experience that the cross section of the rail must have a curved upper surface; that the wheel must be circular; that the horizontal line of the track and the tread of the wheel must be approximate straight lines; and knowing that for an inflexible wheel upon an inflexible track the bearing surface could only be a mathematical point; and that the practical bearing surface can only be obtained by the yielding of material, we learn that to secure any benefit from an increase we must flatten the crown, so that we arrive at last at a greater detriment than the one sought to be avoided.

Years ago when we had only light engines and light rails, though the rail was lighter in proportion than the engine, there was only abrasion, and lamination was unknown. Now, the rail head is frequently rendered useless by lamination before the natural process of abrasion has commenced to reduce it. Rail makers have had their full share of blame for this, and doubtless in many cases with reason; but the best of iron rail, which when tried shows by no test a trace of scoria, graphite, or original lamination, coming from imperfect rolling, yields after being hammered for a time by the driver of the locomotive only a finer lamination than the cheap iron, which has still the divisions of the piling within it. Lamination is the result, then, of some natural and determined law, and that law is this: "That all material when subjected to pressure laminates in planes perpendicular to the direction of the pressure." From this it may be inferred, and indeed it is evident, that the amount of lamination increates with the amount of pressure.

Slaty cleavage, which is only lamination on a mountainous scale, early engaged the attention of geologists, and the opinion of Prof. Sedgwick, who pronounced it the result of molecular polar forces similar in action to crystalline aggregation and cleavage, was fully received. Scorby and others afterwards discussed the cause under other circumstances, and proved from and in regard to it, the law just given in this paper. Later, Prof. Tyndall took up the question. He produced lamination in clay and wax by pressure; tried blocks of ice, and succeeding easily in obtaining lamination along the natural planes of freezing, turned his blocks around and laminated them by careful handling across these planes, thus proving the generality and power of the law. Some of the most interesting derivations and illustrations in his book on glaciers too, come from his use of this phenomenon. Housewives all know how dough laminates under the beating of the roller, when "Maryland or beat biscuits," and other bread of that kind is in process of making up, and maccaroni, which un-

dergoes great pressure, at one stage of its manufacture, becomes leaf-like from it. Tyndall has mentioned all these save the last, and includes the scaling of railroad iron, but looking upon it in the mechanical idea of the running together of cells and imperfections, takes issue with Sedgwick and the early geologists. The writer sees no cause for issue, but regards crystalline and slaty cleavage and lamination as all proceeding from one anterior cause. That cause is this: That all force, whether in the form of light, or heat, or pressure, or otherwise, acts not continuously or by gradual diffusion, but periodically, or in waves.

All vitreous substances have a tendency, when under pressure, to split in cracks parallel to the direction of pressure. This is their received mode of destruction. In examining some crushed glass, the writer perceived that this recognized tendency was even in this substance modified by another tendency to divide into laminæ at right angles to these cracks. Some other facts being noted which showed a direct and close resemblance in their laws of destruction between glass, cast iron, and steel, he was induced to still further investigate by comparing glass beams and columns under different circumstances of pressure. It is well known that when glass is under strain, it becomes bi-refractive, and that in this condition it shows when polarized light is sent through it, the different conditions of strain into which its parts are thrown, both as regards quantity and circumstance, by the intensity, position, and direction of colored bands, shadows, and lines. It would be out of place in a paper like this to speak in detail of the brilliant exhibit of the colored curves of strain of the neutral lines, or rather the neutral spaces as they show themselves to be, or of the mysterious lines, which appear to be neutral in a peculiar sense, that occur amongst the colored curves. Suffice it to say, at present, that when any axis of pressure is traced its course is marked, not continuously nor by gradual diffusions and loss of intensity, but by periodically re-occurring phases. Indeed, the course of the experiments seemed to suggest that an object pressed by a weight derives no additional force from that weight, but that all bodies have within themselves the full quantum of force, necessary for their own destruction, which is only changed from an equilibriated condition to a polarized and effective state by co-ertion. Besides, if compression added destructive force to an object, then tensions should subtract from it, which is an absurd result.

In all cases of glass strained under polarized light, the different phases of strain are marked by different colored curved bands, always yellow, red and blue, transverse to the direction of the force, and the phases of neutrality by dark cloudy spaces. It is as if the original forces in the beam were a quiet crowd of beings, which, by the operation of the coercive force, were suddenly thrown into military line marching against each other from the top and bottom to engage in strife upon the common neutral space laying between them.

But it was possible to treat this law in a more practical manner, and the mysterious lines in the glass columns and beams, rendered meaning by mathematical analysis made this way clear; metallic tubes—as being easiest worked—were compressed carefully in the direction of the axis. The result was, as might have been prognosticated from the glass and from problems. The tubes already compressed in the testing machine of the St. Louis and Illinois Bridge Company were examined and gave the same result. That result was this: That they were wrinkled up transverse to their axis, in waves which were always for the same material a definite distance apart, agreeing with formulæ afterwards derived; the appearance being clearly that of a caterpillar or other uniformly jointed articulata. The formula is this,

$$a\left(\frac{r^2+1^2}{2}\right)^{\frac{1}{2}}=$$

distance from crest to crest of wave, the part under radical sign being general for all tubes, and (a) being a quantity dependent on the material. Several modifications and co-operative phenomena, which it is not necessary to mention here, were also obtained. The main object being to find whether a certain force of pressure being applied to the top of an object, it would be diffused generally through it, or whether it would have its periods of maximum and minimum strain. The latter was found to be the true law and its action to be, that the vertical pressure

upon the extreme top became entirely horizontal at a certain distance below—at twice the distance vertical again—at three times horizontal again, and so on in accordance with the above description of physical effect and the formulæ—which latter was further developed by finding for steel, $a = \frac{1}{3}$, for brass, $a = 5\text{-}6$; the theoretic a, being equal to unity. Softer metals, copper, tin and lead, were also also tried, but with as yet unsatisfactory results, as might be expected. The nature of the colored bands and clouds was thus fully developed. They were phases along the lines of force upon which changes of character took place. The colors themselves, too, are best explained on the supposition, that all the active portions of a beam or column under coertion is made up of minutely narrow spaces of strain alternating with minutely narrow spaces of neutrality, both parallel with the curvature of bands, and consequently perpendicular to the direction of the coertion. This would be another cause for lamination.

Looking then upon a railroad bar as it rests from tie to tie, we can regard it as a beam similarly circumstanced to a similar transparent beam, with the same continuous bearing. This case was also tried in glass, and with the same phenomena, and the writer has no reluctance to assume from the results of the experiments that when the wheel or other weight presses upon the rail, or other object, that a vertical section marks periodic phases succeeding each other similarly to those so p'ain in the more obdurate material, glass, and that along certain re-occurring lines the tendency to divide and separate is much greater than along any intermediate lines. The plane of separation being of course the neutral planes in preference to planes of direct strain, because the force there acts in opposite directions along each side of the the plane. It may be remarked that if glass which generally shows a totally opposite system of yielding, can thus prove our law, the effect must be greatly increased in wrought iron, which structurally characteristically yields in the lammalae direction.

Before proceeding further in respect to the nature of the injury received by the rail, it is well that we should examine the character and quantity of the cause producing the result. Our ordinary locomotive weighs usually about 30 tons. Of this, $\frac{2}{3}$ rests upon the driving wheels, and $\frac{1}{3}$ is lost for adhesion upon the truck. When at rest, then, there is a normal weight of 5 tons for each of the 4 drivers, and $2\frac{1}{2}$ tons for each of the 4 truck wheels. From this cause the engine, as a whole, is unbalanced; a detriment which shows itself in all locomotives constructed with this view of increasing the weight on the drivers for the purpose of adhesion, by causing in rapid motion a galloping and hammering action upon the rail. Mr. Fairlie made some experiments in England, upon engines having a similar arrangement of weights, and states the result as an increase of 4 tons additional thrown upon 1 driver or the other, as the weight shifted in running; thus changing the normal 5 tons weight to 9 tons blow. He also states that a 7-ton wheel will hammer to the extent of 12 tons. As Mr. Fairlie is the inventor of an engine which mainly obviates this defect, I will draw closer attention to the more than corroborative experiments of Baron Von Weber ("Chicago Gazette," February, 1871), from which is deduced an increase of 103 per cent., thus increasing the normal 5 tons to $10\ \frac{15}{100}$ tons. This would appear to be a very sufficient cause when brought upon a space on the top of the rail, probably less than $\frac{1}{2}$ of a sq. in. in area, to achieve any damage of which iron or steel was susceptible.

Starting afresh, then, from our last sentences, and admitting that from the previous reasoning we may accept lamination as caused by a general law, modified by, frequently, but not dependent upon, bad manufacture, it may be asked could any addition of material in the rail, not increasing the bearing or rolling surface, lessen the damage? For myself, I think not. Nay, I think the damage would increase with the additional mass. It is frequently remarked, as an anomaly upon roads where light iron alternates in sections with heavy, and is therefore run over by the same trains, that the heavy iron wears the most; that iron rail is most apt to wear upon, or at the edges of, the ties than between them; more in rock cuts than in softer foundations. And almost all railroad men have heard the legend of the Boston and Worcester or some other road, where, for the greater perfection of

running and gain in economy, the rails were laid upon granite sills, and how the rails and machinery were so beaten up in a short time that the sills had to be dispensed with, and a more yielding substructure substituted. But the Boston and Worcester road was but an item in the long account; almost every railroad man can recollect some instances which, coming under his own observation, have proved to him that rigidity was imperfection.

Come to a more simple and homely trial: place a piece of iron upon an anvil, and strike it with a hammer; the effect of the blow will result from the momentum of the hammer—and the resistance of the anvil. Should the anvil drop as fast as the hammer, there would be no impinging effect; half as fast would result in half the effect; perfect rigidity would give a full effect. Our question, then, narrows down to this: "In what degree does the body of the rail act as an anvil to its own crown, and in how much, if at all, would increasing the mass, and consequent rigidity, add to the anvil-like effect?" Much, it would appear, and more than that: by decreasing the bending of the rail as a beam beyond what may be necessary to preserve its integrity, we but reduce so much of the surface of bearing as has been gained by that yielding.

This is a practical question, and must be answered by experience; and not the experience of one, but the combined knowledge of many. Will not some of those gentlemen, whose track bears us safely across thousands of miles of country—a result necessarily obtained only by great exertion, ability, thought and patience—give some portion of these qualities to the solution of this problem? For in whatever direction the result should turn, its great pecuniary value makes it worthy of attention.

ABSORPTION OF MOISTURE BY BRICK AND STONE.

By JOHN C. DRAPER,

Professor of Chemistry, University Medical College, New York.

From "The American Railway Times."

In the construction of buildings in a climate like ours, it is of the utmost importance that the materials employed should absorb and retain as little water as possible, otherwise the buildings will be damp, and the presence of quantities of moisture in their walls will favor the formation of vegetable growths upon their surfaces, which will, together with the action of frost, aid materially in the process of disintegration.

In a recent investigation of this subject, I selected the following materials, namely, brown stone and Nova Scotia stone of the best quality, fine red Philadelphia brick, and a very compact, hard burned white brick, stamped A. Hall & Sons, Perth Amboy, N. J. Masses of equal size of each were placed in water for twenty hours to allow them to imbibe as much of the fluid as they could take up. They were then turned about on blotting paper as long as they dampened it. The external moisture being thus removed, the masses were weighed, and placed in an air bath at 212 deg. for 3 hours. On being removed from the bath, they were put under a glass bell jar, and being again weighed when cool, were found to have lost the following quantities of moisture:

TABLE I.

Brown stone,	10,000	parts.	lost 260	of moisture.
Nova Scotia stone,	"	"	260	"
Red brick,	"	"	1,179	"
White brick,	"	"	525	"

The masses were then placed in the warm air bath again, and kept at 212 deg. for 4 hours. On being cooled with the same precautions as before, they showed the following losses:

TABLE II.

Brown stone,	10,000	parts,	lost 8	of moisture.
Nova Scotia stone,	"	"	8	"
Red brick,	"	"	0	"
White brick,	"	"	0	"

The masses were then placed on an iron plate, which was heated to a dull red heat, and covered with a hood of tin to cut off currents of air. They were consequently exposed to a uniform temperature, which was sufficiently high to scorch

paper when it was laid on their upper surfaces. The last traces of water were thus expelled, the quantities being as follows:

TABLE III.

Brown stone,	10,000	parts,	lost	17	of moisture.
Nova Scotia stone,	"	"	"	35	"
Red brick,	"	"	"	a trace	"
White brick,	"	"	"	a trace	"

The conditions to which the substances were submitted at the commencement of these experiments on drying, may be regarded as representing their state after a prolonged storm of rain in which they had been drenched and soaked with water for many hours, and Table I. demonstrates that while the brick absorbed more moisture than the stone, the white brick imbibed less than half that taken up by the Nova Scotia stone.

Table II. in its turn shows that stone is far more retentive of its moisture than brick, for, while the former lost 8 parts, the latter lost none. In Table III. the same fact is still more conclusively demonstrated, for against an almost imperceptible loss on the part of the brick, the brown stone lost 17 parts, and the Nova stone 35. We are therefore justified in concluding that though brick absorbs a larger quantity of moisture than stone, it is to be preferred as a building material, since it parts with the imbibed water with greater facility; and, comparing the two kinds of brick together, the white hard burned brick is superior to the red, since it absorbs only half as much water.

Passing from the consideration of the power of retention to that of absorption, I found that, on submitting the thoroughly dried masses of the last detailed experiment to the action of an atmosphere saturated with moisture at 70 deg. Fahr. for 6 days, the following results were obtained:

TABLE IV.

Brown stone,	10,000	pts.	absorb	at 70 deg.	52	of moist're.
N. S. stone,	"	"	"	"	45	"
Red brick,	"	"	"	"	3	"
White brick,	"	"	"	"	3	"

The conditions prevailing in this experiment may be regarded as similar to those existing on an ordinary midsummer day when the dew point stands at 70 deg.; and on inspecting the table we find that, while the brick absorbs but little moisture, the stone is very hygroscopic, the brown stone possessing this property in a more marked degree than the Nova Scotia. Since warmth and moisture, taken together, are peculiarly favorable to the production of vegetable growths, it follows that brown stone is, by virtue of the larger amount of water it absorbs, more liable to disintegration from this cause than the other substances submitted to the experiment. In the case of the bricks the absorptive power is, as the table shows, equal, and very slight or slow in its action. They are, therefore, superior to stone in this respect.

To determine the absorptive power when exposed to conditions similar to those prevailing during a fog, I caused steam from a free opening to play upon them for 3 hours. After cooling for 20 hours they were weighed, with the following result:

TABLE V.

Brown stone,	10,000	pts.	absorbed	147	of moisture.
N. S stone,	"	"	"	110	"
Red brick,	"	"	"	127	"
White brick,	"	"	"	106	"

Which demonstrates that under such circumstances brown stone is more hygroscopic than Nova Scotia stone, and, therefore, affords a more favorable *nidus* for vegetable growths, and is consequently less durable. In the case of the bricks, though the red brick absorbs more fog than the Nova Scotia stone, it is a better building material, since it surrenders its moisture with greater facility. The white brick, on the contrary, absorbs less fog than the others, and dries as easily as the red brick; it is, therefore, the most satisfactory of the building materials submitted to examination.

RUSSIAN PROGRESS IN ASIA.—The Russians appear to consider that by the conquest of Turkestan they have gained a second India, and to be earnestly bent upon improving the natural resources of the new province. The chief improvement on which they pin their hopes is extensive irrigation, by means of which they expect to raise large crops of silk and cotton. A project for irrigating the steppe of Dzizak is at present under consideration, several engineers having been employed by Government in surveying the plain and working out a plan, which, if approved, will be put into operation at once.

THE TEHUANTEPEC RAILWAY AND SHIP CANAL.*

LONDON, *October* 16, 1871.

SIMON STEVENS, Esq.,

President of the Tehuantepec Railway Company, New York.

SIR,—The undersigned, appointed by you, a Commission to examine some of the principal artificial waterways in Europe, with a view of applying the best and most recent experience to the project for an interoceanic railway and ship canal across the Isthmus of Tehuantepec, Mexico, respectfully report, that a portion of our number have examined personally the Caledonian Canal, the great Dutch Ship Canal now under construction for the purpose of establishing an easy and direct communication between the port of Amsterdam and the German Ocean, and also the less known, though very interesting, work now in progress at the Hook of Holland, viz., the new Waterway from Rotterdam to the Sea ("Waterweg van Rotterdam naar Zee").

The members of the Commission have been courteously furnished with every facility for the examination of these interesting works. The Lord Advocate of Scotland, one of Her Majesty's Commissioners of the Caledonian Canal, kindly furnished us with letters to the officers in charge of the canal; the superintendent of which, Mr. Davidson, accompanied us, and explained the more interesting parts of the works. To the eminent engineer, Mr. Hawkshaw, and to his associate at Amsterdam, Mr. J. Dirks, we are indebted for the fullest information, together with plans of the Amsterdam Ship Canal, one of the most remarkable works of engineering of the present day. Mr. Dirks personally accompanied us in our examinations. To Mr. Caland, the chief engineer, and a member of the "Waterstaat" of Holland, we are also indebted for the opportunity of making ourselves personally acquainted with the work at the Hook of Holland, as well as for documents and valuable information.

Want of time (owing to duties or engagements) has prevented personal visits to other great waterways, especially the Suez and Languedoc Canals, which would be instructive in reference to a project for any new ship canal; but these works are so thoroughly described, their characteristics and details so well known, as to enable us to dispense with personal examinations. The various surveys and projects for ship canals at sundry points across the American isthmus, are of course familiar to, and have been attentively examined by us.

A brief memoir of the history of the railway and canal project for the Isthmus of Tehuantepec will be in place here. This isthmus has always, since the early days of American discovery, attracted attention and explorations, as one of the most available points for interoceanic communication; but the project for a "ship canal" first assumed a definite form in the Report† by Señor Moro, founded on a survey made in 1842.

This survey originated in the concession by the Mexican Government to Don José de Garay of the right to open a communication between the Pacific and Atlantic Oceans, through the Isthmus of Tehuantepec, coupled with the condition that the grantee "shall cause to be made at his own expense a survey of the ground and direction which the route should follow, and also of the ports which may be deemed most proper and commodious from their proximity."

Although the communication to be established was not necessarily to be a ship canal, or even (wholly) a water communication, yet it is evident that such a canal, or at least a great canal, was contemplated both by the Mexican Government and the grantee; and the engineer, Moro, expressly states that to such a communication his attention was chiefly directed in making his survey.

In fulfilment of the obligation to make a survey, Señor de Garay immediately dispatched to the Isthmus a Scientific Commission, composed of Señor Gaetano Moro as chief, and Lieut.-Col. de Trouplinière, and Capt. Gonzales, of the staff corps, and Lieut. Mauro Guido, of the navy, as assistants, and Don Pedro de Garay, an

*From the Report of the Commission on the Artificial Waterways of Europe.

†"An Account of the Isthmus of Tehuantepec, with proposals for establishing a communication between the Atlantic and Pacific Oceans, based upon the Surveys and Reports of a Scientific Commission appointed by Don José de Garay. London, 1846."

officer of the Ministry of War, as secretary. The Commission spent 9 months upon the Isthmus in the execution of its task. It fixed the position of the more remarkable points by astronomical observations or by triangulation, measured the most important altitudes by barometric or trigonometric observations, and explored in a general way the more important watercourses and harbors; and furnished, so far as it went, a tolerably accurate account of the Isthmus in its geographical and topographical relation to the question of a canal, and gave very valuable information concerning the mineral wealth, and the natural and agricultural productions.

Señor Moro based upon this survey a project for a canal 20 ft. in depth, and 50 miles in length, connecting the upper waters of the Goatzacoalcos, on the Gulf side, with the lagoons of the Pacific coast. The summit was at Tarifa, at about 680 ft. above the level of the sea.

Further than to make the survey mentioned, nothing was accomplished by Señor de Garay with regard to executing the canal. After the acquisition of California by the United States, this route acquired a new importance as a means of communication with our newly acquired Pacific territory. Could possession have been obtained at once, Tehuantepec would probably have become the established route of communication, owing to the great saving of distance over Panama, as well as the salubrity of the climate.

Soon after the close of the war between Mexico and the United States, the franchises and privileges of Señor de Garay, became the property of Mr. P. A. Hargous, of New York, who in connection with a company formed in New Orleans, assumed the rights and responsibilities of the Garay-grant. But the necessary negotiations with the Mexican Government, and with other parties interested, delayed a commencement of operations till December, 1850, at which time the Company having applied to President Taylor for an officer of engineers to direct the survey, Brevet-Major J. G. Barnard, Captain of Engineers, was detailed for that purpose. The aspect of the problem was at this period peculiar, the great object being to establish at the earliest possible day an available route for the great flood of travel between our Atlantic and Pacific coasts. Hence the idea of a canal was put aside, and that of a railroad substituted. The survey then ordered was therefore organized and executed solely in reference to a railway and a preliminary and auxiliary wagon road, and these it was urgent to establish with the least possible delay. These facts not only shaped the whole character of the survey, but they even altered the route. It was necessary to extend these roads at once to the Pacific (instead of striking the lagoons as the canal would do); and the "Ventosa," or "Salina Cruz," were the most available points for the Pacific terminus.

Instead of passing over Moro's summit (Tarifa), the more westward passes of Chivela and Masahua were surveyed. Hence the survey under Major Barnard not only did not coincide with Sr. Moro's at the summit, but the entire route between the seas was quite different from that which a canal would occupy. The survey thus executed may be said to have been commenced in the end of December, 1850, and substantially terminated early in the following June (1851). Its results are so fully set forth in the Report of the Survey, prepared by J. J. Williams, one of the undersigned, that we need only state that it established the practicability of a railway route at moderate expense, and with grades not exceeding 60 ft. per mile, and with a summit about 800 ft. above the level of the sea. The passes surveyed were not supposed to be as low as the more eastern one of Tarifa, and no observations whatever were made, specially directed to the practicability of a canal.

In the year 1857 the railway project was resumed and a new survey executed under the direction of W. H. Sidell, now Lieut.-Col. of Infantry and Brevet Brigadier General, U. S. Army, a distinguished civil and railway engineer, the object being a final location of the road. This latter survey was made with much care and expense. Upon its results and the previous surveys the line of location has been definitely laid down, the cost of construction estimated, and everything established necessary to the issuing of specifications for contracts for the execution of the work.

Since the revival, under the impulse of the successful execution of the Suez Canal, of interoceanic canal projects, the claims of the Isthmus of Tehuantepec for favorable consideration have gradually acquired a pre-eminence which was at first denied.

The virtual failure of all the recent explorations instituted by the United States Government to find a practicable route where the Isthmus is narrow—as at Panama and Darien—and the superior advantage of geographical position of Tehuantepec, its healthfulness, and its vast local resources for the construction of such a work, and its established practicability, in an engineering point of view, for a canal with locks, are now understood, and must have their weight.

In describing the different surveys that have been made, we have reserved mention of the most recent; and in reference to the establishment of the "practicability" which we have claimed for the canal project, the most important. We allude to the survey made during the last winter and spring by Captain R. W. Shufeldt, of the United States Navy, by order of the President of the United States, in pursuance of an Act of Congress for that purpose, and with the co-operation of the Mexican Government, for the special object of determining the question of an adequate water supply.

The final report had not been transmitted to the Navy Department at the date of our leaving the United States, but the authenticated copies of preliminary reports have been furnished you by the Hon. Secretary of the Navy, and are given in full in the appendix of this Report.

We have in them, from the highest source and in the most positive form, the important conclusion, "that an interoceanic canal of any necessary dimensions may be constructed across the Isthmus of Tehuantepec." We have also the further statement of the engineer on whose exploration Captain Shufeldt bases his own dictum (just quoted), "that a ship canal across the Isthmus of Tehuantepec is not only practicable, but also that the topography of the country presents no extraordinary obstacles to its construction."

The latter statement that "the topography of the country presents no extraordinary obstacles to the construction of a canal," is but a confirmation of the information obtained from Major Barnard's, Mr. Sidell's, and Señor Moro's surveys. The railway surveys and location passing over a line nowhere actually coinciding with the probable line of location of a canal, does not of course furnish the means of exhibiting a profile of such a location; but most of the country through which it would lie has been traversed by Major Barnard's, Mr. Sidell's, Mr. Williams', or Moro's parties. Moreover, it should be borne in mind, unlike the country over which explorations have been recently carried across the Darien Isthmus, through wildernesses entirely unknown to civilized man, of which a single line of survey will furnish but very meagre information, the Isthmus of Tehuantepec has been a thoroughfare for centuries, while for the last 30 years surveying parties have been, at intervals, traversing it from shore to shore, either with instruments of precision in their hands, or subjecting it to scientific reconnaissances. With these preliminary remarks, we will proceed to define the probable line of location for a canal, commencing at the summit.

The summit determined in 1852 by Señor Moro was near Tarifa. This selection was confirmed by incidental examination during Major Barnard's and Mr. Sidell's surveys,* and has now been once more confirmed by the survey of Captain Shufeldt. This summit level was barometrically determined by Señor Moro as being 680 ft. (206 metres) above the level of the sea. The precise determinations of the elevation of the contiguous (railway) summits of Masahua and Chivela authorize the belief that the above statement of Moro is near the truth. The descent towards the Pacific plains (elevated at the foot of the mountains about 240 ft. above the sea) would be either by the "Portillo de Tarifa," or penetrating the small "Cerro del Convento" by the valley of the Monetza to its junction with the Chicapa, and thence by the valley of the latter river. The latter route furnishes the greater development (say 10 or 15 miles) for reaching the plains. Either route is believed to offer no extraordinary difficulties, though doubtless this descent is the most formidable work of the project. No tunnel is necessary, and

* "As Principal Engineer of the Commission under Major Barnard, while making explorations and a survey for a railroad across the Isthmus in 1851, I took occasion to examine the dividing ridge over which Moro had made his surveys for a ship canal in 1842; and although I did not pass over the entire route as surveyed by Moro for a ship canal, still I was at Tarifa, the summit, and on the most difficult ground over which he proposed to construct it, and I think I am safe in pronouncing the route, as surveyed by him, the most practicable of any yet explored."—*Report of J. J. Williams*, 1870.

It is also worthy of remark that in the report of Major Barnard's survey the "Rio del Corte" was indicated by the same engineer as a probable source of adequate water supply for the summit level of a ship canal. See page 245 of his Report.

the difficulties will lie in locating the bed and locks of a great canal along a descending mountain pass, in which the necessary excavations must be mostly in rock.

From Tarifa to the Portillo or to the Cerro del Convento, the distance is about 4 miles, measured over a plain so level that in the rainy season it becomes inundated. To depress the summit below the level of this plain would require a deep cutting extending several miles. Such a cutting, even to the depth of 100 ft., in relation to the magnitude and importance of the work, of which it would form an inconsiderable part, would hardly be thought formidable; and the resulting advantage of reducing the number of locks, and placing the summit more conveniently in reference to its supply of water, may quite probably demand it.

We shall therefore assume that the canal summit is not over 600 ft. above the sea. The descent to the plains at the foot of the mountain would therefore be 360 ft., requiring 36 locks of 10 ft. lift. From the foot of the mountains the canal, descending through 240 ft. with the natural slope of the plains, would reach the Upper Lagoon in a distance of about 14 or 15 miles.

The main source of water supply of the summit, as determined by the survey of Captain Shufeldt, will be from the upper waters of the Rio del Corte, at a point some 25 to 30 miles from Tarifa. The route of a feeder was carefully surveyed, with transit and level, by Mr. Fuertes, chief civil engineer under Captain Shufeldt, who found it entirely practicable. Mr. Fuertes finds the supply furnished by the Rio del Corte, and other available sources, at its lowest stage, to be 2,000 cubic ft. per sec., or 120,000 cubic ft. per min.

From the summit towards the Gulf of Mexico, the canal would follow the well-defined route of the valley of the Tarifa and Chichihua rivers, to the junction of the latter with the Malatengo. Crossing the latter stream, it would strike the Goatzacoalcos at Old Mal Paso, which river it would cross at that point.

The route from Tarifa to the Malatengo and Goatzacoalcos is thus described by Señor Moro :—"This part of the country is the most fertile and pleasant that it is possible to imagine. Shortly after leaving Tarifa, it is truly interesting to observe, mixed together, the spruce and fir-tree of the cold climates, the oak of the more temperate, and the palm-tree of the warm regions. Further on, these trees, as well as beautiful green meadows of vast extent, occur alternately, with woods of a luxuriant tropical vegetation. Trees of precious woods, wild cacáo, vanilla, etc., are everywhere seen. The plains near the rivers, cultivated by the inhabitants of El Barrio, Santa Maria Petapa, and San Juan Guichicovi, give an idea of the astonishing fertility of the soil, since the natives only come in time to burn down the brushwood, and sow without cultivation, scarcely ever revisiting their corn-fields until the harvest time."

Various considerations caused the left bank of the Goatzacoalcos to be preferred for the railway surveys; but there is no doubt that the proper location of the canal is on the right bank. A diminution of length by some 40 miles, the avoidance of transverse ridges (easily surmounted by a railway), the fewer crossings of streams, and the avoiding of the overflows—all are considerations uniting in its favor.

From the Lagoons to the summit at Tarifa, and from that point to the crossing of the Goatzacoalcos, the line is so well defined as to leave but the mere details to be determined. From that point the canal, to avoid the great Suchil bend of the river to the westward, would follow, as near as practicable, its chord, crossing the Chicolote and the Chalchijapa, and approaching the Goatzacoalcos again near the source of the Coahuapa. This region is a dense forest. Observations taken from the summit of Mount Encantada, authorize the belief that it is unbroken by any great topographical irregularities. The only considerable streams to be crossed (this statement applies to the whole route) are the Malatengo, the Goatzacoalcos, the Chicolote, and the Chalchijapa. The second named is by far the largest. The ordinary rise and fall is 17 or 18 ft; but in exceptional seasons it is stated to have risen higher. The point of proposed crossing has been selected on a thorough knowledge of its favorable character.

From the Coahuapa to the junction and termination in the Goatzacoalcos River,

the proposed route lies through a country nearly level.

The entire length of purely artificial canal thus approximately located, will be from about 115 to 120 miles. The number of locks would be 120 in all, assuming a summit of 600 ft., a lift of 10 ft., and also, as we have a right to do, that there will be no secondary summits.

We have now to speak of the harbors. The Goatzacoalcos, for 30 miles from the Gulf of Mexico, forms an excellent harbor. Its access is over a bar having 13 ft. at low water (according to the recent survey of Captain Shufeldt).* This bar is unchanging, and we anticipate no serious difficulties in attaining a navigable depth of 20 ft. or upwards. From the bar up to the point where the canal (as we have described its location) terminates, a distance of about 30 miles, the river is generally over 20 ft. deep. At a few points there are but 15 or 16 ft. depth. Of course, to adapt this portion of the river to a ship canal, will require channel improvements, and perhaps some rectifications in its course—no work, however, of great magnitude.

On the Pacific, the Upper Lagoon furnishes a basin in which, in the region occupied by the islands, and thence to the canal Santa Teresa, a depth of water of about 20 ft., with a mud and shingle bottom, is found.

To reach the ocean, one or both of the narrow peninsulas, which separate the lagoons from it, must be cut through, and an external harbor, or entrance piers, thrown out similar to those now under construction at the North Sea terminus of the Amsterdam Canal. The works at Suez, those at Amsterdam, and those of a very different character at the mouth of the Maas, yet having much in common with them, and with that which we are now proposing, are sufficient proof that, to modern engineering, the establishing of a good entrance to these lagoons, for vessels of large draught, is quite practicable.

In the railway surveys it was important to reach the best existing port on the Pacific. Ventosa was first selected. Neither this point nor Salina Cruz is considered eligible for the canal, owing to the advantages the lagoons offer for a capacious harbor, and the diminution in length of artificial canal and avoidance of river crossings; but it is interesting to know that there are already secure anchorages in the close vicinity of our proposed entrance to the canal.

The statements given in former reports* show that the formation of an external harbor on the Pacific coast, which will afford entrance to the lagoons, is fraught with no probable difficulties, and that the coast is not a dangerous one, and that there now exist in the close vicinity safe anchorages.

It would be quite premature to attempt an estimate for the work we indicate. Surveys of the line can alone determine the data upon which one can be made. But we state with confidence that, for the length of the line and height of summit, it is rare to find a route so devoid of engineering difficulties. Moreover, the isthmus furnishes every variety of building material, while from its population, and that of the States of Oaxaca and Vera Cruz, can be drawn, at no expense for transportation, a hardy laboring force quite adequate to execute the work. The soil of the isthmus and of the contiguous regions, affords in abundance sustenance for such a force. The climate throughout is healthy even to European laborers. With a native force sickness is not to be anticipated. Hence, some of the most formidable difficulties and sources of expenditure in the construction of inter-oceanic routes, at other more southern points of the American isthmus, are not encountered on the Isthmus of Tehuantepec. The cost of earth and rock excavation or masonry, should not exceed, on the Isthmus, the cost of similar works in Europe.

In this connection we express our hearty concurrence with the views of M. Thomé de Gamond, in his "Avant projet," for the Nicaragua canal, projected by M. Felix Belly. M. de Gamond says: "We think that, after the example of the Dutch and the Americans, it is important to make extensive use of timber instead of masonry. The San Juan river traverses a virgin forest, furnishing trees of great dimensions, both in diameter and height. These timbers belong to the 'Concession,' and

* The survey of Lieut. Leigh, U. S. Navy, in 1848, gave 12½ ft. *at extreme low water of Spring tides.* There has probably been slight if any change.

* Barnard's Survey.

can be employed in unlimited quantity, with no other expense than that of the carpenter's work. To overlook the value of these gratuitous resources, and to prefer masonry merely because masonry is more durable and more monumental, would be to increase expense for an empty satisfaction."

Again he says: "It would be an error to think that we can, in this enterprise, copy works executed in Europe under the formal rules of construction there adhered to. It is necessary, above all things, for the accomplishment of such an enterprise, to lay under contribution the immense local resources of nature, and to utilize in the employment of these resources that which is most applicable in the distinctive genius of every nation."

All that is said above by M. de Gamond applies perfectly to Tehuantepec. The immense forests of the most valuable and durable timbers which lie along the route should furnish the material for locks, bridges, and aqueducts, by which the expense of these otherwise most costly structures will be reduced to a fraction of that which masonry would require.

The use of timber in the United States for locks and aqueducts and bridges is so common that we need not refer to examples: to adopt its use at Tehuantepec is but to adopt the principle of M. de Gamond, and to apply the "distinctive genius" of American construction to an American work, and at the same time to "utilize" the immense constructive resources offered us in the forests of Tehuantepec.

In what precedes we have given no "dimensions" for the proposed canal. It would be premature in this report to do so. But it should be understood that we refer to a SHIP-CANAL, with an availabe depth of not less than 20 ft., and locks of corresponding dimensions (say of 450 ft. in length and 50 ft. in breadth). The present transition state of ocean navigation, in which a substitution of steam for sails, and of steam vessels of enormous length for existing models, furnishes an independent and adequate motive for the use of timber for locks. While it would be imprudent to hamper navigation by "monumental" constructions of dimensions which might prove inadequate to the future, it would certainly be premature to build, in masonry, locks of the enormous length that some shipbuilders anticipate iron steamships are destined to attain.

We have but to add that the proposed railway, owing to local resources, and the extent of rich and productive countries which would come tributary to it, would command a lucrative traffic independent of interoceanic movements, and would be almost an indispensable auxiliary in the construction of a canal, in which capacity alone it would pay for its own construction.

We are, Sir,

Respectfully, your obedient Servants,

J. G. BARNARD,
Colonel of Engineers, Bvt. Major General, U. S. Army.

J. J. WILLIAMS,
Chief Engineer, Tehuantepec Railway Co.

JULIUS W. ADAMS,
Engineer Public Works, City of Brooklyn.

THE POROSITY OF CAST IRON.

From "The Mechanics' Magazine."

The crystalline structure of cast-iron renders it peculiarly susceptible to leakage by the passage of liquids and gases through its substance. The former require pressure to force them through the body of the cast iron, while the latter are assisted by heat. A familiar example of the passage of water through cast iron is that of the hydraulic press. In some cases this leakage is very severe, and diminishes the working power of the apparatus in a very large degree. Of course the castings for these presses require to be run in a special manner, and the iron used should be of as fine a grain as possible. They should be cast with a good head of metal, and, where possible, under pressure. In cylinders of large size, and consequently of great thickness, the run of metal should be continued after the proper quantity has apparently been admitted into the mould. The metal should, moreover, be pressed or rammed into the mould, so as to render the casting as sound and close

as possible throughout, by supplying the contraction in cooling. Without these precautions, and often with them, the iron will sometimes prove faulty near the waste head of metal. This was the case with the first cylinder cast for the large presses used in raising the Britannia tubular bridge. The internal diameter was 1 ft. 10 in., the diameter of the ram being 20 in.; the cylinder was 6 in. thick, its external length being 9 ft. 1½ in., and the length of the stroke 6 ft. The weight of the finished press was 13 tons 16 cwt.; but, on account of the great head of metal requisite in such castings, 21 tons of iron were run into the mould.

The first cylinder was cast bottom upwards, and, notwithstanding that every precaution was taken to feed the mould for many hours, it proved faulty. The cylinder was turned and finished externally and internally, but, on cutting off the waste head of metal at the bottom of the press, a spongy hollow space was found in the centre of the metal capable of containing upwards of a pint of water. This cylinder was consequently rejected, and the next one was cast with the bottom downwards in its natural position. By this means the most sold metal consequently occurred at the bottom of the press, and the more porous metal at the top. To condense this as much as possible, a head of nearly 7 tons weight was run on the top and afterwards cut off; the metal was fed to the mould for 6 hours after the casting. But with all these precautions the press proved to be leaky at the top. The remedies prescribed by Mr. Edwin Clark consisted in adding a second leather collar beneath the original one, in hammering the cylinder, and in forcing into the pores of the metal a thick gruel made of oatmeal and sal-ammoniac. The filmy particles of the oatmeal were thus mechanically fixed in the pores by the corrosion produced by the sal-ammoniac. Instances have occurred in practice when hydraulic cylinders of great size have been made of wrought iron with external rings of the same metal shrunk on them. These of course come expensive, and as cast-iron, from its very nature, will leak under pressure, the best thing appears to be to dose it well with Edwin Clark's gruel.

The passage of gases through the pores of cast iron, to which we have referred, is quite another matter, and refers principally to close stoves made of that metal. The question involved here is one of great scientific interest, and is important in a sanitary point of view. We are most of us familiar with the unpleasant condition of the atmosphere in a room heated by a close stove. It was, however, on the continent—where this method of heating apartments is extensively adopted—that the practical bearing of the question was first discussed, and we are indebted to Dr. Carret, one of the physicians to the Hotel Dieu in Chambery, for originally bringing it under notice. That gentleman, a few years since, drew the attention of the Academy of Sciences to the subject in a series of papers, in which he dealt with the evil consequences of the use of cast-iron stoves. Little interest, however, was excited in the matter at the time, but General Morin subsequently brought the matter forward with better success. Dr. Carret plainly denounces cast-iron stoves as an absolute source of danger to those who use them, and he bases his denunciations upon the following somewhat conclusive facts:—During an epidemic which prevailed in Savoy, Dr. Carret observed that all the inhabitants who were affected by it used cast-iron stoves which had recently been imported into the country. On the other hand he observed that all those who used other kinds of stoves or adopted other modes of firing escaped the disease. Another circumstance bearing on the same question occurred in the Lyceum of Chambery, where an epidemic of typhoid fever broke out. This outbreak is regarded by Dr. Carret as being influenced by a large cast-iron stove in the dormitory of that establishment.

General Morin endorsed Dr. Carret's statement and opinions, and laid before the Academy of Sciences the results of some comparative experiments which had been performed by the Doctor and which supported his theory. He had a room heated to 40 deg. Centigrade by means of a wrought-iron stove, and after having remained in it for an hour, he perspired freely, had a good appetite, and felt no sickness whatever. Similar results attended the use of an earthenware stove, but very different were those which followed half an hour's confinement in the same room warmed to a similar temperature by a cast-iron stove. Here the ap-

petite failed, and an intense headache and sickness were brought on. MM. Deville and Troost, both eminent physicists and investigators, have established that both wrought and cast iron—the latter in an eminent degree—become pervious to the passage of gas when heated to a certain temperature. They have been enabled to state the quantity of oxide of carbon which may, as they suppose, transude from a given surface of metal. They have also shown that the air which surrounds a stove of cast iron is saturated with hydrogen and oxide of carbon. They conclude that cast-iron stoves when sufficiently heated absorb oxygen and give issue to carbonic acid. In the lecture-room at Sarbonne, M. Deville placed two electric bells, which were capable of being set in motion by the diffusion of hydrogen or oxide of carbon, in the room. Soon after lighting the two cast-iron stoves in use in the apartments, the bells began to ring, thus illustrating the correctness of his theory, and showing the danger of stoves of this metal.

We have thus looked at the question of the porosity of iron from 2 different aspects. The first concerns mechanical and the second sanitary engineers. The first means a purely professional, the second a semi-social aspect. In either case the circumstances are interesting and important, and the remedies are, in the one, to fill up the pores of the iron with gruel, and in the other to avoid the use of cast iron in close stoves. The latter question probably affects France more than it does England, but, inasmuch as a great number of cast-iron stoves are in use, it behooves our sanitary friends and the public to take this matter into serious consideration.

MILL FOR MIXING CONCRETE.

We give on page 137 a drawing of a new concrete mixer, designed by Bvt. Major-General Gillmore, and used by him during the past season in the construction of the fortifications on Staten Island, New York.

The drawing is taken from the fourth edition of "General Gillmore's Treatise on Limes, Hydraulic Cements, and Mortars," just issued, and represents the machine as employed by General Duane on the fortifications in Portland harbor, Maine. The mill consists of a cubical box, made of hard wood or boiler iron, measuring 4 ft. on each edge, in the inside.

It is provided on one face with a trap door about 2 ft. square, close to one of the corners through which the box is charged and the mixed concrete emptied out.

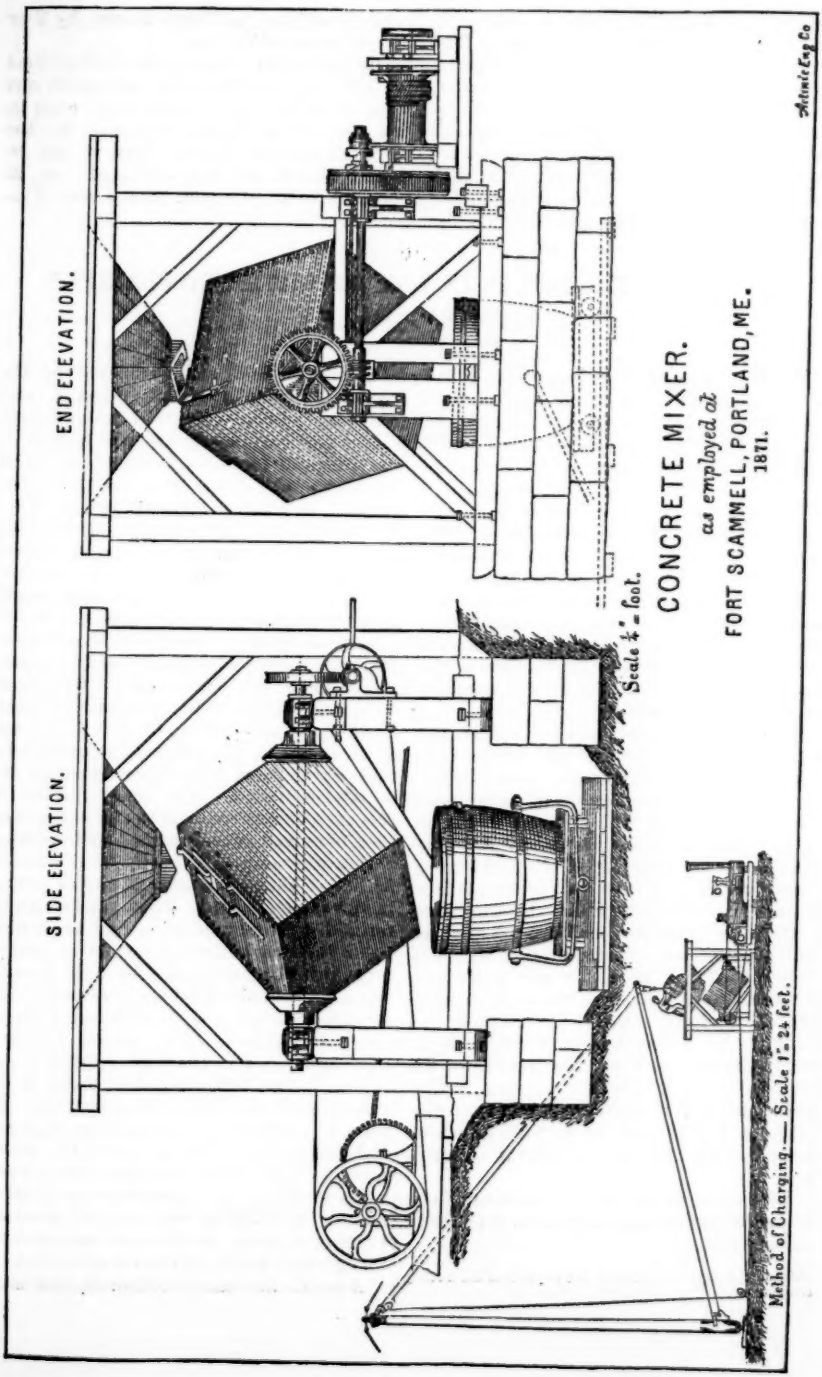
The box is mounted upon and firmly fixed to an iron axle passing through opposite diagonal corners.

By means of a cog wheel attached to one end of the axle, and worked by a screw, a revolving motion is communicated to the box.

The box is charged by means of a large bucket suspended from a crane of sufficient sweep to reach the mortar bed on one side and the piles of broken stone and gravel on the other. The same bucket is used in conveying the concrete mortar and the coarse materials into the box, one measure of the mortar alternating with from 2 to 3½ measures of the broken stone (or gravel, or a mixture of both), depending on the quality of the concrete required.

If the capacity of the bucket is one barrel, say 4 cubic ft., a suitable charge for the box when making Portland cement concrete, will be, 2 buckets full of mortar (8 cubic ft.); 5, 6, or 7 buckets full of mortar, coarse material (20, 24, or 28 cubic ft.); 2 buckets full of mortar to 7 of the coarse materials; the ingredients of the mortar having been proportioned with the same view to economy, will produce a concrete containing the least admissible quantity of the cementing substance.

In making Rosendale cement concrete the charge will generally be, 2 buckets of mortar (8 cubic ft.); 4 or 5 buckets of coarse material (16 or 20 cubic ft.). Eight revolutions of the box, made in less than 1 minute, are found to be quite sufficient to produce the most thorough incorporation of the mortar with the broken stone and gravel. Every piece of stone, and every pebble and gravel become completely coated over with mortar. Indeed the trituration of the contents of


END ELEVATION.
SIDE ELEVATION.
Scale 4' = foot.
CONCRETE MIXER.
as employed at
FORT SCAMMELL, PORTLAND, ME.
1871.
Method of Charging. — Scale 1" = 24 feet.
Atlantic Eng Co

the box is so complete, that it is not necessary to mix the mortar beforehand. The ingredients of the mortar, the cement, lime (if lime be used), sand and water, after being properly proportioned by measure and rudely mixed together with shovels, require no further preparation, but may at once be placed in the box with the coarse materials. After mixing, the trap door is opened and the contents deposited on the platform below, by 2 or 3 revolutions of the box.

One box of the capacity above described ($4' \times 4' \times 4'$ on the inside) will easily mix from 95 to 100 cubic yards of concrete in one day of 10 hours, and will do the work very much better than it can be done by hand, and at a saving of from 20 per cent. to 25 per cent. in the cost of labor.

ON WATER METERS AS IN USE BY WATER COMPANIES.*

By Mr. JOHN REID, F. R. S. S. A.

From "The Engineer."

Mr. Reid at some length explained the functions of the water meter, and some of the difficulties attending its construction, due to the non-elastic character of water and the conditions under which it is supplied and drawn off for consumption.

Water meters may be divided into two distinct classes: low-pressure and high-pressure meters. The first are represented as a class by those which discharge definite quantities of water by successive and intermittent actions out of measuring chambers of known capacity into cisterns situated underneath for its reception, the mere weight of the water being generally employed as the moving agency.

The high-pressure class delivers the water at higher levels than themselves, and are impelled in some cases by the mere velocity of the current of water passing through them, but in most instances by the pressure alone. A variety of working models and drawings of the best known forms of meters were exhibited and explained, in most of which the working parts were numerous and complicated, as well as costly in construction. Mr. Reid then stated that he had some years ago studied the subject, with the view, if possible of devising something simpler and cheaper as a water meter than those already known, and as the result of his labors exhibited, for the first time, a diagram and a working model of a meter prepared and fitted up by himself, of which he gave the following general description:

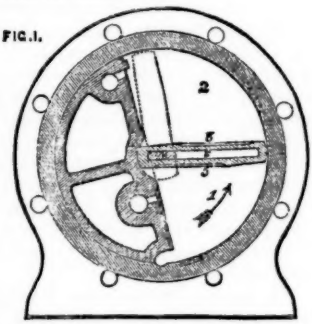
Instead of employing the ordinary form of piston, traversing a cylinder alternately from end to end, and hampered by the friction of packing, stuffing-boxes, and multiplicity of movements, I have adopted a light and easy-fitting metallic piston of a rectangular form, revolving on one of its edges around the axis of a short cylinder, while its opposite edge sweeps the inner circumference of the cylinder, and moving so freely that a few inches of water pressure would be sufficient for its impulse. The small amount of leakage that might pass the edge of the piston is not to be measured by the greater or lesser head pressure of water, but is obviously proportioned to the resisting weight of the piston only, and therefore the amount of such leakage per revolution or per action has to be added to the volume discharged by each stroke, and taken account of by the registering index. The chief novelty in this instrument consists in the compound kind of movement performed by the piston within the measuring cavity of the meter. Although the piston always moves round in the same direction, it cannot be strictly termed a rotary motion, and as it does not return backwards it cannot be termed a reciprocating motion, although partaking a little of the semblance of both. The second peculiarity is in differing from all other water meters, in which the sole moving agency is the water pressure; in my contrivance the impelling force is derived from the water pressure and the force of gravitation, acting alternately and independently. The action of the piston he likened to what takes place when turning a card over on one edge on a table, sliding it back to its original position, turning it again in the same direction on its opposite edge, and so on as before.

A short discussion followed, and most

*Abstract of paper read before the Royal Scottish Society of Arts.

of the members who spoke complimented Mr. Reid on the simplicity and ingenuity of his invention. Professor Fleeming Jenkin said he had a very high opinion of the merits of the invention, and he ventured to hope that the Society might claim the honor of first having had before it the coming meter, which was to enable the public to check the enormous waste of water prevailing in all great towns. The cordial thanks of the Society, he thought, were due to Mr. Reid.

FIG. 1.



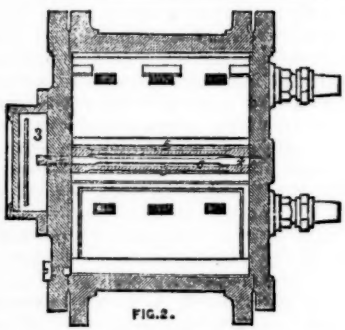
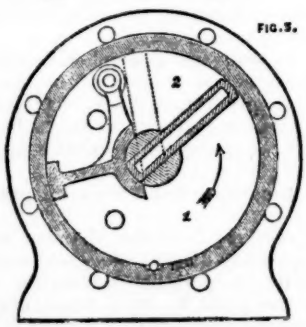


FIG. 2.

FIG. 3.



The annexed diagram and description will better explain the general construction and action of the instrument:—

Figs. 1 and 2 are vertical sections at regular angles of the instrument, Fig. 3 is a modification. The measuring chamber 1, 2, is a cylindrical segment rather larger than a half-circle; the counter wheels or index are within a glass-fronted box 3, and are acted on by the revolving spindle 4. The piston 5 is rectangular, and is connected to the spindle, passing through a slot in the piston, or the piston may itself pass through a slot in the spindle, as in Fig. 3. One edge of the piston 5 works in contact with the inner surface of cylinder, whilst the opposite edge works into a concentric cylindric cavity of smaller radius formed in the chord side of the chamber. The chord side of it is vertical or inclined, the inlet for the liquid is below the central cavity, and the outlet is above it. When the piston is in the position shown, the liquid entering below lifts it upwards and round the course till nearly parallel with the chord, at which time the lower edge of piston escapes from the central cavity, and slides down by gravitation over or through the spindle, and thus translating the axis of revolution from one end of the piston to the other, when it again ascends by the pressure of the inlet from below, while the liquid above is forced outwards by the ascending piston through the outlet port above. The opposite sides of the piston at the ends are slightly bevelled off to insure the piston sliding down just before it comes in contact with the chord surface.

THE officers of several German railways have again reported on the necessity of notching the bottom flanges of rails, and it is stated by one railway company that, on a line laid with cast steel rails without notched bases, a dangerous longitudinal shifting of the rails occurred. Generally, however, the practice is not found injurious, though it is thought preferable to have it done at the ends of the rails only, the corners of the notch to be carefully rounded off in all cases.

M. HESLING states, in the "Journal de Pharmacie et de Chimie," that even long before milk becomes sour there are generated in it very small organized spores of an Ascophora species.

THEORY OF THE ATMOSPHERIC ENGINE.

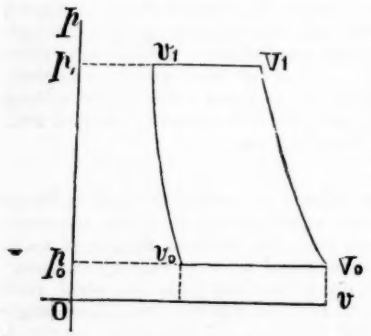
By EMILE LECLERT.

Translated from "Annales du Genie Civil."

I. It is easy to trace the diagram of a thermic atmospheric engine by generalizing Watt's method.

In our theoretic apparatus, in order to obtain conditions clearly defined, we shall suppose that the walls of the containing vessel are impermeable to air. We shall suppose that an apparatus consisting of a *working cylinder*, draws the air into the heating chamber with a tension p_1 and a temperature t_1 and passes it into the atmosphere; while another apparatus, a *feed cylinder*, supplies the heating chamber with air at a temperature θ_0 and a tension p_0. These are generally the constituent elements, whatever may be the combinations.

For greater simplicity we shall construct our diagram for 1 kilog. of air driven into the chamber, and 1 kilog. of cold air taken from the atmosphere, so that it may be the expression of the work realized by a kilogram of fluid. We take the cylinders, with a section of 1 square metre; so that, estimating the tensions p



in kilograms to the square metre, the elementary work corresponding to a slight displacement of one of the pistons, may be represented by the rectangle of the sides; one representing the displacement, the other, the tension p; and the volumes generated and paths described by the pistons will be expressed by the same numbers.

This being assumed, the quadrilateral $v_1\ V_1\ V_0\ v_0$ in the figure, referred to the axes—one of pressures, the other of volumes—will give the following relations: The abscissas of the points are designated by the letters at the several points.

1. The working cylinder introduces into the heating chamber 1 kilog. of air, with pressure p_1 temperature t_1, and corresponding volume, V_1. This kilogram of air afterwards loses its tension, and its volume increases with diminishing tension, according to a law represented by the curve $V_1\ V_0$, a law which is suited to the case of gas confined in an envelope impermeable to heat. Expanding till its tension falls to p_0, its volume being V_0 and its temperature t_0, it is then discharged into the atmosphere. The area $p_1\ V_1\ V_0\ p_0$ represents the work obtained per kilogram and communicated to the heating chamber.

2. The feed cylinder takes a kilog. of air from an atmosphere at the pressure p_0 and the temperature θ_0 and with a corresponding volume v_0. This kilog. of air is then driven back; its volume decreasing with the increase of pressure, according to the law represented by the curve $v_0\ v_1$ (a law which is suited for the compression of gas in an envelope impermeable to heat) until its tension reaches p_1, that of the heating chamber, its volume being v_1, and its temperature θ. The area $p_0\ v_0\ v_1\ p_1$ shows the work per kilog. communicated to the heating chamber.

The difference of the two areas above given, *i. e.*, $v_0,\ v_1,\ V_0,\ V_1 = S$, represents the total work to a kilogramme of air, actually realized, in the complete action of the apparatus.

II. To study an atmospheric engine is to calculate and discuss all the elements of the diagram $v_0,\ v_1,\ V_1,\ V_0$. At each of these vertices $v_0,\ v_1,\ V_1,\ V_0$ are to be considered the groups of quantities $v_0,\ p_0,\ \theta_0$; $v_1,\ p_1,\ \theta_1$; $V_1,\ p_1, t_1$; $V_0,\ p_0,\ t_0$.

On the other hand each kilogram of air—

(1) receives from the chamber a certain quantity of heat of q_1 heat-units, to pass with temperatnre θ_1 from the point v_1 to the point V_1, with temperature t_1;

(2) gives up a quantity of heat q_0 in passing from the temperature t_0 of the point

V_0 to θ_0 of the point v_0. If a denotes the specific heat of the air under constant pressure, a quantity considered independent of the pressure, then

$$q_1 = a\,(t_1 - \theta_1) \text{ and } q_0 = a\,(t_0 - \theta_0).$$

This specific heat a is to be distinguished from the specfic heat under constant volume, which we shall call b, and represent by a constant number.

The difference $q_1 - q_0$ is a quantity which disappears in the action of the apparatus.

The area S, the value in kilogrammetres of the work obtained, obviously depends on the elements which the diagram determines.

The laws of Mariotte and Guy Lussac are admitted as true (within practical limits of tension and temperature). If v denotes the volume of 1 kilog. of air at the temperature t and tension p, the quantity

$$\frac{v\,p}{1 + a\,t} = c$$

is a constant number.

The first question is to determine the nature of the curves $v_0\ v_1$, $V_0\ V_1$ of cut-off in an envelope impermeable to heat.

Now the abscissas of these curves are constant, that is

$$\frac{V_0}{v_0} = \frac{V_0}{v_1} = h \qquad (1.)$$

These curves being traced, it becomes possible to calculate S by ordinary methods. But the theory of heat furnishes us with a remarkably simple and convenient relation. The ratio of S to the quantity of heat disappearing, *i. e.*, $q_1 - q_0$, is a constant number E; which is what is called the mechanical equivalent of heat. Hence

$$S = E\,(q_1 - q_0).$$

or

$$S = a\,[(t_1 + \theta_0) - (t_0 + \theta_1).]$$

III. To discuss the expression, let us suppose the temperature of the air to be θ_0; that of heating t_1. S will be a maximum when $t_0 + \theta_1$ is a minimum. Let us find the condition of this minimum. Since h (1) denotes the ratio of the dilatation of a kilog. of air passing from θ_0 to t_0 under a constant pressure p_0; then

$$\frac{1 + a\,t_0}{1 + a\,\theta_0} = h. \qquad (2.)$$

From θ_0 to t_1 under same pressure let the ratio for same volume be

$$\frac{1 + a\,t_1}{1 + a\,\theta_0} = H.$$

$$\therefore \frac{1 + a\,t_1}{1 + a\,t_0} = \frac{H}{h} \qquad (3.)$$

But it is a property of the curves $v_0\ v_1$, $V_0\ V_1$ under these circumstances that

$$\frac{1 + a\,t_0}{1 + a\,\theta_0} = \frac{1 + a\,t_1}{1 + a\,\theta_1}.$$

Hence

$$\frac{1 + a\,\theta_1}{1 + a\,\theta_0} = \frac{1 + a\,t_1}{1 + a\,t_0}.$$

and by (3)

$$\frac{1 + a\,\theta_1}{1 + a\,\theta_0} = \frac{H}{h} \qquad (4.)$$

Adding (2) and (4)

$$\frac{2 + a\,(t_0 + \theta_1)}{1 + a\,t_0} = h + \frac{H}{h}$$

This found, H is a quantity determined by the data of the question, as long as h varies with t_0. It will be seen that, in the last equation, the product of the two terms in the second number is constant and equal to H. It follows directly from a familiar theorem of algebra that $t_0 + \theta_1$ is a minimum when

$$h = \sqrt{H}, \text{ that is when } t_0 = \theta_1.$$

Hence this conclusion: In the case of a maximum diagram the temperatures of air at entrance and discharge of the working cylinder are equal.

In Ericsson's engine the ratio of p_1 to p_0 is less than that given by the maximum diagram; *i. e.*, $\theta_1 < t_0$. Ericsson caused both the discharged air at temperature t_0 and the supply air to pass over the same series of metallic sieves. These may be regarded as a recipient of heat capable of imparting to the discharged air at t_0, an amount of heat afterwards to be transmitted to the air at the point of entering the heating chamber whose temperature is θ_1.

If, in an engine, $h = \sqrt{H}$, the equality $\theta_1 = t_0$ follows. In this case the metallic sieves are of no use. If $h < \sqrt{H}$ or $\theta_1 > t_0$ they become a disadvantage.

COAL has been discovered in Rajpore and Kummun, in the territories of his Highness the Nizam. Miners have been sent to ascertain the extent of the seams.

RESULTS OF THE GAUGE CONTROVERSY.

By T. McDONOUGH.

Written for "Van Nostrand's Magazine."

So much has been written by men of ability on both sides on the question of broad versus narrow gauge, that it would seem as if evidence enough had been offered to allow us to sum up the matter And that conclusions might now be drawn which would show satisfactorily to which of them preference should be given; or at least, if neither of them is best applied to all roads, the reasons why one of them is better adapted to certain classes of roads than the other, should be deduced.

Although the narrow gauge advocates claim that economy both in first cost and also in operating is in their favor, the economical results are not alone to be considered in a decision of the question. The owners and those who operate the broad gauge roads seem to unite in their opinion that the system of distribution by means of the wide gauge having already compelled the abandonment of most of the exceptionable gauges, is now too well established to be broken up for the uncertain advantages that a narrower one may offer; even admitting the advocates of a narrow gauge make their claims good, and this is not wholly conceded. For example, should a road diverging from Springfield, Mass., adopt the 3 ft. gauge it would not only be cut off from the roads in that State centring at Springfield, but from the benefits of distribution throughout the West. Wheat from any part of that great granary can now be contracted for, to be delivered at any point on a railroad within a radius of 30 miles from Springfield without breaking bulk, and return freights made in like manner; but all such comity of commerce would be thrown into confusion by introducing another gauge and with it a Babel in the railroad world.

It should be noticed that by viewing the narrow gauge as a change to be made from a broad one by taking out a central section lengthwise of the road, the amount of masonry, earthwork, and ties, that is saved is but small; and also that the principal economy in construction is derived from the use of a lighter rail; but when it is proposed to adopt such a rail on roads of the ordinary gauge, with an equipment to correspond, and in this way to gain the principal advantages of the narrow gauge, viz., cheaper construction and less dead weight to haul, the answer is made that such a course would be going backward, that the heavy rail has displaced the light one from the demands of traffic, and that as economy of haulage has gradually increased the weight of the engine to 30 tons and over, the heavy rail is a necessity, and though more costly, it gives a better return than a lighter one would do with engines hauling lighter trains, and that 40-ton engines with full loads on 60-lb. rails give a better return on the capital sunk than 20-ton engines on cheaper rails.

It would seem that nothing could be advanced against such facts; the weight of the rail being governed by that of the engine, and the economy of heavy loads being admitted, that no improvement could be made by adopting a lighter superstructure.

But it is possible that the discussion of the gauges may bring about a result similar to that which has been reached in the medical profession by the advance of homœopathy, which promises to cure by infinitesimal doses, against the regulars, who relied on the *quantity* they administered. The Faculty, whilst ridiculing the theory, go so far as to adopt it partially, by giving smaller doses than formerly, and mankind is the gainer, without deserting the regular profession; and in like manner the roads with the uniform gauge may be gainers by adopting the strong points of the narrow gauge, without departing greatly from the system approved of by past experience. The necessary weight of rail in both systems is determined by the load on the drivers, as the load on each wheel of the cars is usually much less than that on the drivers.

One of Fairlie's double truck engines on the narrow gauge, weighing 20 tons, has 2½ tons weight on each driver. One of the ordinary gauge 30-ton engines, with 20 tons tender, has usually the same adhesion of 20-ton, but each of the drivers carries from 5 to 7 tons, requiring a proportionally heavy rail.

In one case, the adhesion due to 20

tons weight of engine is all utilized with a weight of 2½ tons, tending to crush the rail at any one point, and in the other there is the adhesion from 20 tons also utilized out of 50 tons weight, but with 5 tons or more crushing the rail, which must be made more than twice as heavy as in the first case. It is evident that an improvement is desirable which will utilize more of the dead weight, whilst the weight upon a single wheel is lessened at the same time, and this must be done without complicating the machine, or lessening its ability to conform to roads already built.

The weight now thrown on a single wheel in freight cars may amount to 3½ tons; should the weight on the driver be reduced to that amount, a 40-lb. rail could be substituted for the 60-lb., and the substantial saving of the narrow gauge construction gained.

The following sketch of a plan to reach this end with only slight changes in the present machine, is offered as a suggestion that may lead to something practical when the importance of the result is more generally appreciated than it seems to be at present.

Taking the machine as now built, put 4 coupled drivers under the tender with 14 tons weight upon them, and throw the same weight upon the engine drivers, that is 28 tons for adhesion with 3½ tons on each wheel, the same load which the car wheel carries, the remainder of the weight of tender and engine will be thrown on the truck wheels. With such an arrangement of drivers, 4 under the tender and 4 under the engine, the power must be transmitted from the engine to the tender drivers, without cramping the freedom of the tender to conform as now to the curves of the road. It is proposed to do this in the following manner: The tender and engine are to be coupled by a centre-pin, and a shaft with cranks on its ends is to be held vertically over the tender axle which is nearest to the engine and about 6 ft. above it, by 2 bearings from that axle, so that the shaft must move vertically with it and not be affected by the springs of the tender. In like manner the horizontal movement of this shaft will be governed by 2 rods that connect it with the rear axle of the engine. This additional shaft would then be supported and controlled by 4 bearings, each 2 of them resembling a letter A with one leg vertical over the tender axle, and the other inclined and reaching the engine axle; with the shaft at the vertex of the A. The power is to be transferred by rods from the drivers on the engine, connecting their crank-pins with pins in the cranks of the additional shaft, and thence to the tender drivers. This arrangement would permit the axles of both engine and tender to conform to the radii, which cannot be done with any that has been proposed heretofore.

Some arrangement similar to this which will give increased adhesion and less weight on each wheel, without the complication of the Fairlie double engine, will insure to the present gauge the principal advantages in construction of the narrow one, without any essential variation in that type of road which is the result of past railroad experience.

A CLASSIFICATION OF STEEL.

By THOMAS M. DROWN.

From "The Bulletin of the American Iron and Steel Association."

Steel-producing processes have of late years multiplied so rapidly, that it is by no means an easy matter to keep track of them all, much less to remember the nature of each individual process. A comprehensive classification of the different methods of making steel, combined with a simple nomenclature, would not only be a great assistance to the memory, but would also serve an useful purpose in clearing away the fog of mystery with which the subject of steel-making is enveloped in the minds of many. An exhaustive classification was made by Wedding of Berlin, some time since, and published in the "Berg-und Huttenmannische Zeitung," October 29, 1869. It was, however, almost too detailed for ordinary purposes, and an attempt to translate the same into English involved the coining of so many polysyllabic words, that the result bordered on the ludicrous.

The classification, which I desire to propose, has at least the merit of simplicity and conciseness. The main divisions only are provided with names. Suitable

designations for the subdivisions were very much to be desired, but it is doubtful whether they would ever be generally adopted. I therefore content myself in pointing out clearly the natural divisions of the subject, so that any variety of steel can at once be classified.

I. CRUDE STEEL.

1. From the ore direct, by reduction and carburization. Ore steel.

2. From pig iron by decarburization. Pig iron steel.

(*a*) By means of gaseous oxidizing agents (air, steam, etc.). Ex. Bessemer process, etc.

(*b*) By means of solid oxidizing agents (ore, saltpetre, etc.). Ex. puddling process, Heaton process, etc.

B. From wrought iron by carburization. Wrought-iron steel.

(*a*) By fusion with pig iron. Ex. Martin process.

(*b*) By fusion with coal or carbonaceous matter. Ex. Mushet's process, Indian process.

(*c*) By heating in charcoal—without fusion. Ex. cementation process.

(*d*) By heating in atmosphere of carburetted hydrogen — without fusion. Ex. Macintosh process.

II. FINE STEEL.

1. By fagoting crude steel. Shear steel.

2. By remelting crude steel. Cast steel.

To go further into the details of manufacture would only serve to complicate the classification. The object in view is to present clearly the main feature of every process.

It will be evident, on a moment's reflection, that the raw material for steel making must be iron ore, pig iron, or wrought iron. In the case of ore, the process consists mainly in reduction and carburization. This can be effected by gaseous carbon (carbonic oxide, carburetted hydrogen, etc.), or by direct mixture of the ore with coal. The resulting product may be required to be subsequently fused or otherwise treated, yet the main feature of the process is the reduction of the ore.

In the second subdivision where pig iron is used, the object is the removal of carbon, silicon, manganese, etc., which is effected by oxidation, the agents employed being either free gaseous oxygen, as in the case of air, or oxygen in combined solid form, as in the case of ore, saltpetre, etc. Here the iron may be molten as in the Bessemer and the puddling process, or simply at a red heat, as in the process for making malleable castings.

Where wrought iron is used the process becomes a carburizing one. The carbon added may be in form of carburetted hydrogen, in form of charcoal or carbonaceous matter, or pig iron may be used in proportion to its amount of carbon. As in the previous case, the conversion may take place both with and without fusion.

There are many processes which may be assigned to more than one of these divisions. Thus the Bessemer process belongs mainly to the division I., 1, *a*, inasmuch as the decarburization of the pig iron is effected by a current of air. But as ordinarily practised the result of this operation is the production of wrought iron, which is subsequently converted into steel according to division I., 3., *a*, that is by the addition of pig iron. No classification could be made to take into account all the details of a process without becoming cumbersome ; it is sufficient for our purpose to indicate the most prominent feature of a process.

The fusion of wrought with pig iron is placed under the head of wrought iron steel, as in this case, the wrought iron greatly preponderates.

There are, further, varieties of steel, which are named after substances which enter into their eomposition as : Titanium steel, Chrome steel, Tungsten steel, etc, These can be arranged in the above classification by prefixing their characteristic names, as : Titanium pig iron steel.

Again, there are many steel processes in which an essential feature is the employment of substances to remove impurities, as sulphur and phosphorns. These might be designated by affixing the name of the substances employed to the steel produced. Thus in the case of the Heaton process we would have pig iron steel by saltpetre, in the case of the Sherman process pig iron steel by iodine.

These terms, it must be confessed, are somewhat unwieldy, yet their descriptive nature may in some respects render them preferable to those in ordinary use.

The classification may also serve the purpose of showing at a glance the possibilities involved in the manufacture of steel.

LOCOMOTIVE WORKING EXPENDITURE.

From "Engineering."

It is but a short time since we directed attention to the somewhat abnormal position which a locomotive occupies amongst steam engines generally as regards the small opportunities it affords for being worked with a greater economy of fuel. A locomotive with its imperfectly protected and unjacketed cylinders, placed in a position which facilitates the carrying into them by the steam of any water mixed with the latter, cannot be declared a high class type of steam engine; but it is nevertheless a type which has done good service, and it is, moreover, one which it is difficult to modify with any really economical results under the circumstances which govern locomotive working. As we pointed out in our former article, the great obstacle to the improvement of the locomotive engine as a steam user is the small number of hours per annum during which such an engine is actually working. This small proportion of working time limits the annual monetary saving which any given improvement can effect, and renders the charge for interest on the additional cost of any such improvements disproportionately large. Taking the mean gross cost of an engine as £2,400, and the mean annual cost of fuel as £180 per annum, we showed, on the occasion to which we have referred, that even if, by doubling the cost of an engine, it was possible to save the whole cost of fuel without incurring any extra charges for depreciation and repairs, the saving would but pay interest at the rate of 7½ per cwt. per annum on the extra outlay. The sum above taken as the annual cost of fuel per engine, namely, £180, was deduced from an examination of the accounts of ten of the principal English railway companies for the last half year of 1870; but we this week publish on page 310 a table giving a more complete account of the expenditure on 20 of our principal lines, which will enable us to found our deductions on a broader basis.

The Table referred to—which, we believe, will be regarded with much interest by a large section of our readers—contains data derived from the locomotive accounts of the various railways enumerated for the first 6 months of the present year, and from it we find that the average cost of fuel per engine during that period was £72, or at the rate of £142 per engine per annum. Now, if we assume, as we may justly do, that any improvement made in a steam engine should pay, on an average, at least 15 per cent. per annum (5 per cent. for interest on capital, and 10 per cent. for depreciation) on its original extra cost before it can be regarded as being a source of economy, we find that any improvement capable of saving 10 per cent. of the fuel used, must, if applied to a locomotive, cost less than £100, or that otherwise such an improvement will not prove really an economical one. This deduction agrees with that made in our former article, namely, "that any fuel-saving appliances added to a locomotive must, to avoid their use being attended with a loss, effect on the average a reduction of fuel amounting to 1 per cent. for each £10 of their original cost." This, it must be borne in mind, is an average result, and it is one also applicable to individual lines of great extent and variety of traffic, such as those of the London and North-Western, Great Northern, and similar companies. But although this is the case, a closer investigation of the Table shows us that there are certain lines on which the conditions of working are so exceptional that the above deductions entirely cease to be applicable. This, for instance, is the case with the North London Railway, where the cost of fuel per annum is £264 per engine, or nearly double the average; and still more noticeably so in the case of the Metropolitan Railway, where the annual cost of fuel per engine rises to £528, a sum more than 7 times the average, and more than 10 times that incurred per engine per annum on the London and North-Western Railway. The effect of this on the expenditure which it is justifiable to make on fuel-saving improvements is very striking and, in fact, it will be seen that, whereas, on the average, any improvements which are capable of saving 10 per cent. of fuel should not cost more than £100 per engine, in the case of the Metropolitan Railway such an improvement might be profitably employed even if it increased the cost of each engine by £700. In making

this statement we are, of course, supposing that the improvement is of such a character that its maintenance would not involve an annual charge greater than 10 per cent. on its original cost. In the same way we find that on the North London line an additional expenditure of about £190 per engine, would be justifiable for the purpose of obtaining a reduction of 10 per cent. in the consumption of fuel, and a similar statement would apply to the London, Brighton, and South Coast Railway. In the case of the Metropolitan Railway the high cost of fuel per engine per annum is due partly to the high price of the superior kind of coke which it is necessary to employ on that line, partly to the heavy work to be done, and partly to the great mileage obtained from the engines. This mileage, it will be noticed, is more than 80 per cent. in excess of the average, and is nearly 8,000 miles per annum greater than it is on any other line in the country. The causes we have above enumerated place the Metropolitan Railway in quite an exceptional position, and afford opportunities for the employment on it of economical expedients which would be inadmissible on other railways.

Turning now to the data given in the Table, concerning the expenditure of oil, tallow, etc., we find the average annual cost per engine for these materials to be £32. Applying the same rule as before, namely, that any improvement must effect an annual saving equal to at least 15 per cent. on its original cost, we find the average maximum justifiable expenditure to be about £2 per engine for each 1 per cent. of lubricating materials the improvement is capable of saving. In the case of the North Staffordshire Railway, however, where the cost of oil, tallow, etc., is £60 per engine per annum, an expenditure of £4 per engine might be incurred to obtain a saving of 1 per cent.; while on the Great Western, where the annual cost of lubricating material is but £18 per engine, an expenditure of about 18s. per engine would be justifiable to effect a similar economy.

Taking the average results recorded by the Table, we find the various items which go to make up the total of locomotive expenditure to be as follows :

		Per cent.	
Salaries, office expenses, and superintendence....			2.35
Running expenses:	Wages	29.7	
	Fuel	24.1	
	Water	2.	
	Oil, tallow, etc.	5.35	
			61.15
Repairs and renewals:	Wages	19.4	
	Materials.....	17.1	
			36.5
			100.0

Taken altogether, the statistics contained in the Table which we publish this week, entirely confirm the arguments—founded on less complete data—which we have used on previous occasions when writing of locomotive economy. Leaving out of the question such exceptional cases as the Metropolitan, the whole bearing of the evidence available is to the effect that, in the case of a locomotive engine, improvements tending towards economy of fuel are of secondary value as compared with such improvements of construction as will enable a greater annual amount of work to be got out of each engine by reducing the time lost in making repairs; and that in proportion as the work done per engine per annum is increased, so also will be increased the opportunities for the employment of refinements tending to produce economy of fuel.

PROPOSED ROMAN EXPLORATION.

From "The Builder."

Fresh notice is being attracted to the subject of the exploration of the buried relics of Rome, archæological or artistic, to which we called the attention of our readers last September. Mr. J. H. Parker, C.B., whose excavations in Rome have already led to discoveries of no small value, is again in the field. He proposes to raise a fund of £50,000 by way of capital of a limited company, to be formed with the object of purchasing land in Rome, exploring it to the utmost, and then reselling it—it is presumed at a profit—for building purposes. There can, we apprehend, be but little doubt that explorations such as Mr. Parker and his friends have now, for some time, conducted in the Eternal City, will in future only prove practicable under widely different conditions. While the incubus of

priestly government brooded over Rome, the very pride which even the Italian peasant takes in the relics of the ancient glories of the country was extinguished by the harsh tyranny of greedy ignorance. Rome, though still calling its chief dignitary by the Pagan title of Pontifex Maximus, claimed to be regarded only as a Christian city. The walls of Romulus, the *cloaca* of Numa, the temples of Republican times, were only to be endured in ecclesiastical Rome if christened and whitewashed. Even the very names of that earlier time, with which the essential forms of the Papacy are so much more closely connected than its advocates choose to admit, were often whimsically travestied in monkish garb. It is difficult to recognize the *Xystus vetus* under the title of Santo Sisto Vecchio, or the *Mutatorium Cæsaris* in San Cesareo; but transmutations of the kind may serve to show the manner in which Roman antiquity was dealt with by Romish ingenuity.

No doubt can be entertained that English archæologists will find their position at Rome very different under the Italian Government, from what it was under the Papacy. The great object, under the latter, was to collect *bajocci*, under all and every pretext. To attract foreigners to spend money in the city, was the sole industry of Rome of late years. Even such mites as the payment of rent or damages for leave to dig were not to be despised. Nothing can be more characteristic than a little incident casually mentioned by Mr. Parker. Last winter, under the friendly offices of the Monks of St. Gregorio, he obtained permission of their lessee to open a pit in a garden belonging to the convent, for the consideration of £10. The pit was accordingly sunk to the depth of 24 ft., and discovered the well-known pavement of the Via Appia, and fragments of the travertine gateway built by Domitian for the Porta Capena; showing that there were two archways to this gate. No sooner, however, had the excavation proved thus productive of information, than the *locatario* comes down on the straightforward Englishman. £10 was the price for opening the pit. That bargain was settled. Now the pit must be filled up again. There was no bargain for keeping it open! So good Mr. Parker had to pay a further sum of £20 for permission to keep his pit open for 6 months!

This is only a characteristic instance of the manner in which Englishmen, bent on historic research, are regarded in Rome. How much can be got out of them is the one question; nor, we will venture to assert, is any foreigner safe from plunder, unless he avails himself of the services of an Italian lawyer. These gentry alone, from long practice, can meet the fertile and inexhaustible ingenuity of their own countrymen in what they call matters of business, but which we, poor simple islanders, are apt to regard as ably-utilized opportunities for swindling.

Now without supposing that any great moral change has been effected in the Roman citizen by the hoisting of the Italian tricolor on the Quirinal, it must be borne in mind that the state of things has undergone a great alteration. The new Government, though inheriting very much of the spirit of the old, yet owns some deference to the public opinion of Italy, and, perhaps, some to that of Europe. It cannot afford to wrap itself up in contemptuous indifference. It may be, and we believe is, quite as reluctant to do any act of justice that involves parting with a grain as was either of the most corrupt Governments which it displaced. But it must at all events put some face on the matter, which it was not necessary for its predecessor to do. Now the Italian people take a great pride in all visible proofs of their former grandeur. Not a peasant so dull but he respects the relics of antiquity. This respect must be evinced by the Government. Exploration and restoration, even if they cannot be made self-supporting, form a popular mode of giving employment to some of the legion of idlers who seek to eat the bread of the country; and the prosecution of works of this nature looks respectable, both at home and abroad. Thus the uncovering of Pompeii is being steadily prosecuted, at the expense of the State, under the able and modest direction of the Chevalier Fiorelli, who, as private secretary of H.R.H. the late Count of Syracuse, had the care of much of the archæological research carried on at the expense of that unfortunate Prince. Then the Italian Parliament has voted £12,000 for the purpose of excavating the whole of the Pala-

tine Hill, with the slopes round it, as far as the Forum Romanum and the Arch of Janus on the north, the Via Sacer and Clivus Sacer on the east, the Arch of Constantine on the south, and the Circus Maximus on the west. Already have discoveries been made which indicate that the pestilential condition of Rome is due rather to the constant violation of the laws of health, whether as regards the decency of the living or the disposal of the dead, than to any mysterious terrestrial *miasmata*. Even supposing, then, the anxiety of the Government for discoveries to be real and practical, it would be their duty to supervise all excavations carried on in Rome ; to see that their course and consequences were strictly subordinated to sanitary considerations, and that they formed integral portions of some well-considered and comprehensive plan.

Now, if we were to learn that an Italian Archæological Society had been formed for the protection of Avebury or of Stonehenge, for the restoration of Uriconium, or for the excavation and leaving open those portions of tesselated pavement or other Roman work which have been, within the last few years, discovered in London, we should hardly be apt to treat these volunteers with too much gratitude. After all, it is not clear whether a better case could not be made out for an Italian protectorate of English—or rather, Roman—archæological remains in this country, than for an English occupation of those of Rome. The Italians do respect their relics,—the English, as a people, do not. The rapid destruction of some of the grandest relics of an unknown past which has taken place, since the time of Stukely, at Avebury, would have been an offence against the public law of Italy, and would have been repressed by authority if (which is most unlikely) any Italians had been found brutal enough to attempt it. Then the great military roads that opened our previously pathless forests ; the fortified camps which have left their names, in the form of the affix of Chester, in so many counties, even as they have left traces of the normal plan of the Roman *Castrum* in the 4-way streets of Gloucester, and many other cities of Roman origin ; the actual remains of imperishable reticulated brickwork, or of tesselations, the materials of which were taken from yet older buildings ;—in all these things the Italians of to-day have a hereditary interest even more direct than our own. Nor can we, on any possible grounds, pretend to so much right to explore Italy as an Italian archæologist might claim for the exploration of England.

Under these circumstances, we think that the plan now suggested, should it meet with enough support to assume a definite and digested form, is perhaps the only one under which it will be feasible for English enterprise to make any satisfactory progress in the recovery of the ancient historic evidence of Roman archæology. To purchase land, at a fair price, in the open market ; to investigate thoroughly all structural remains ; and subsequently to sell the land for building, is a scheme in itself possible. Moreover, it has the advantage of not being one altogether of an eleemosynary character. There is some prospect, if not of a return, at all events of a dividend, of the original subscription to the subscribers. Many a man would be likely to contribute his £10 on the understanding that, if not exactly an investment, yet it was a purchase of a chance. Archæological knowledge would certainly be increased, if the money were wisely expended. And the fair probability would remain that the shares might be worth their nominal value.

Of course, something distinct and definite will be announced by Mr. Parker as the arrangement in virtue of which he invites subscriptions. Some board of directors must be named, some responsible trustees for the proposed investments. Above all, it will be desirable that intending subscribers should be informed under what legal advice their money is to be laid out. On this, indeed, the whole stability of the project will depend, so complicated are the claims affecting landed property in Italy, and so usual is the appearance of some lurking prior mortgage, after the purchase money has been paid, that a degree of caution quite foreign to our English habits is necessary in any transaction of this nature in that country. Moreover, it is necessary, to avoid trouble hereafter, that the good-will of the Government should be assured. Here, again, an Englishman will naturally inquire what possible effect can the good or ill will of a Government have on the purchase of property from the owners? He will find

that in this case it has much to do with it. The powers of interference with his proceedings are great, and may be exercised, at the instigation of some insignificant enemy, in a very annoying manner. Objects of art, for instance, are claimed by the Italian Government as a sort of treasure-trove. Wherever a claim of this kind exists, are to be found all sorts of rights of inspection and conservation that may prove intolerably vexatious if any ill-feeling exists. Mr. Parker tells us that he has obtained written permission from the Italian Government to make excavations in any part of Rome. Of course, in coming forward as a promoter of a company, he will desire to discharge himself of any unnecessary responsibility, and will take care to print and publish the exact text of this permission. It will be necessary also to show that the local laws with reference to public companies are exactly and formally complied with. In fact, there is a good deal which must be done before subscriptions to a limited company can with propriety be received.

We treat of the subject with much sympathy with Mr. Parker. He has devoted much time, labor, and money to the service of archæological discovery. Laboring under the disadvantage of the absence of a professional education, he has yet produced works that are valuable to the architectural student as well as to the archæological amateur. To say that he has a hobby, is only to say that he is one of those men to whom science is generally indebted for most of the impulses to its pursuit. To say that he makes mistakes, is only to say that he is one of those whose discoveries are not limited to the side of the highway. He has spent, he tells us, half of his fortune in Rome; and it would be well for the world if the pursuit of unwritten evidence had many such disinterested votaries. His discoveries have been neither few nor small. His labors have been incessant. Our own hearty concurrence, moreover, is due to the moral tendency of his labors. At a time when criticism has pushed its analysis to the extent of absolute destruction of our records of the past, it is very much to find a man who comes honestly forward to say, "Romulus was not a mythical personage, for here is the masonry of his wall; Roman history is not a series of fables, for here are the traces of kings, consuls and emperors." If Mr. Parker went no farther than he has done, he would rank as a benefactor to the most important of sciences, the philosophy of history. It is the more needful that he should be kept free from any entanglement with what he has himself experienced to be a very untrustworthy administration; and that any investment of English money, to such an extent as $50,000 in Roman land, should be placed under the most formal guarantees competent to the laws of the country and to the administration of the kingdom. Long and bitter experience has taught us how ready the various Italian Governments are to encourage the flow of English money to fertilize the long arid soil, either of the wastes around Brindisi or of the valleys covered by the *debris* brought down by the Po. But when it comes to question of return,—*Hic labor hoc opus est.* The old maxim that no faith is to be kept with heretics appears still to be honored at Florence. Englishmen, we know, *are* heretics.

Mr. Parker suggests no less than 30 explorations and excavations to be pursued in the coming winter. Among them, that which strikes us as the most important, serving in no small manner as a key to more, is the completion of the marble plan of Rome, attributed to the 3d century, and mentioned by the historian Panvinius. Fragments of the plan were discovered in 1867, in an excavation undertaken by the monks of S.S. Cosmo and Damiano. Its completion, and publication by means of a permanent photographic process, is not only most important as an archæological proceedure, but would be of great service to the exploration as furnishing a sort of block plan, by reference to which the course of discovery can be conveniently indicated.

The incidental mention made of this important record of ancient topographical science, as the 22d out of 30 objects proposed for investigation during the coming winter, is an indication, in our opinion, of the main cause why the efforts made for the exploration of Rome, no less than those for the exploration of Jerusalem, have hitherto attracted so much less public support than the actual importance of each subject demands. Professionally, educated archæologists are very rare.

Very imperfect views are but too common as to the relative value of the remains of different eras of structural art; and prehistoric archæology is much confounded with architecturel antiquity. Hence it happens that interest in the actual discoveries of other people is not uncommonly very vivid. Many a man may find pleasure in grubbing about on his own account, turning up, with equal content, a denarius of Carausius, or a silver penny of Queen Anne, who cares but little to know what discoveries are in progress in the adjoining county. Again, many a man may be capable of making a good survey, of grasping the military features of an ancient fortification, of tracing the course of an aqueduct, or of carrying out detail after detail of local investigation, who has not the logical and orderly grasp of mind needed for the clear enunciation of the great historic problems to be illustrated by the result of his toil. And again, a man thus fitted to direct a survey of the kind, can only, by the rarest chance, have the habit of the publicist, the power to bring before the world, clearly and incisively, the main outlines of his case, in such a manner, as to win or to command attention. It is certain that this must be done, in order to attract the interest of any large portion of the public. Of Rome every one has heard, and of Jerusalem every one has heard; but what we may expect to discover in either locality, for what we should look, and what will be the value of the discoveries we seek,—these are matters which the public must have explained to them, not only before they will take the trouble to send post-office orders but even before they will so much as read through a column of details in small print in the daily papers. In this preliminary statement of their object, illustrated, year by year, by the clear description of the successive discoveries, each referred to its proper head, both the Roman and the Palestine explorers have been signally deficient. In the latter case it is the less excusable from the block outline which we ourselves supplied ("Builder," 4th January, 1868) of the 7 successive cities that have been reared on and around the hill of Zion; the 18 successive architectural eras indicated by history; and the locality, or other features, distinctive of each. To burrow at haphazard, lighting now on a coin of the Seleucidæ, now on a lamp of the Arabic caliphs, now on a balistic ball of Titus, and now on a charred fragment of the cedar roof of Solomon's porch, is interesting enough for those who are engaged in the pursuit, but will never attract public support, unless as the detailed and orderly prosecution of a well-arranged scheme.

The exploration of Jerusalem, however, while it cannot claim support on the ground of such personal and disinterested exertion as Mr. Parker has devoted to the exploration of Rome, is illustrated by two important features, the excellence of which we cannot too strongly urge the latter investigators to copy. The admirable education of the Royal Engineers, in surveying and mapping country, has been turned to the best account in Palestine; and the Ordnance maps which have been completed and engraved, are permanent contributions of great value, both to topography and to geography. Again the photographs taken by the non-commissioned officers of the same corps are clear, well-defined, and effective.

In the repeated exhibitions to which Mr. Parker has invited us, of the products of his own labors, we have had more than once to regret want of due attention to these two important particulars. A map of Rome and its environs, on which the various discoveries could have been indicated, would of itself have been a valuable production, and would have enabled people to see at a glance what was in hand. The definition of Mr. Parker's photographs, as a rule, has been extremely imperfect. Out of more than 2,000, there are but few that any one would care to look at as pictures. As records they are, no doubt, of much value, though the appearance of the prints does not promise any permanence even of their present indistinct details. One-fourth of the number of views, taken with artistic selection and with mechanical beauty, would have set many of us half wild after the exploration. It is not the case that the climate of Rome is naturally unfavorable to taking good negatives in the camera; for those taken by M. Braun, and reproduced by the carbon process, are some of the most admirable works ever yet effected by any branch of graphic art. If the services of this photographer are available, a very few prints from his factory would be

worth a great number of inferior, *quasi*-amateur productions.

In Rome itself exist relics of the cradle of European society. While Regal, Consular, Imperial and Papal Rome are not divided from one another by the broad lines of fire and of steel that Nebuchadnezzar and Titus drew across the walls of Jerusalem, still the principal buildings of the various eras, however grading into one another, are to be recognized by well marked features. Portions of the *Arx* of Romulus yet remain on the Palatine Hill. The stones employed are 4 ft. long, 2 ft. wide, and 2 ft. deep. They are split off from the tufa quarries by means of iron wedges, exactly as these quarries are worked in the present day, and do not appear to have been dressed, or but roughly so, with the axe. The building of the later kings shows some reduction in the size of the blocks. Fragments of the wall of Servius Tullius are to be found on the eastern side of Rome, running on the high ground for a mile, and connecting, by a great *agger*, the several *arces* of the famous seven hills. In this wall the stones are wrought and closely fitted, and secured to one another by iron clamps, not run in with lead. From these samples of the art of the mason 2,600 years ago, down to the most finished and splendid productions of the time of Hadrian, archæology can trace both the progress of the builder's craft and the growth and development of the city. In the catalogue of photographs, printed in 1868 by Mr. Parker for private circulation, are to be found a valuable historic series of the successive styles of work, and a general distribution of the photographs into appropriate classes. It is much to be regretted that this arrangement was not carried on and perfected. The catalogue of the 1,800 photographs exhibited in New Bond street last year is without any order except that in which the photographs happened to be taken. Mr. Parker's materials are rich; his knowledge is extensive. For such a systematic programme as we have indicated, he could readily supply ample data. The authorities for dates, very briefly referred to in his preface last year, should be distinctly set forth. The general scheme of his researches, divided into historical chapters, should follow. Results already obtained, referred to their proper heads, would then be regarded in their proper light; and archæological and historical students, seeing what was actually in hand, would be likely to strain their energies to find Mr. Parker the support which he requires.

Whatever be the complexity, or even the error, of detail, whoever be the laborers—the Archæological Society of Rome, the newly-projected company, the Italian Government, or any native and private explorer—the value of a competent survey of Rome cannot easily be overestimated. We have good hope that the time has now arrived when this important object will be steadily and worthily pursued. However much or however little may henceforward be effected by English funds, it must not be forgotten that Oxford has sent forth a pioneer, who labored for the elucidation of Italian history while Italy was no more than a geographical expression. The mere presence at Rome of Englishmen able to pass educated criticism on the efforts of Signor Rosa (which seem to be rather in the direction of what is called restoration than of discovery proper) is important. The whole of learned Europe will listen with interest to clear and impartial accounts of any attempt to draw back the veil of so many centuries. We are happy to call attention to the present proposal of Mr. Parker; and we need not say that we heartily wish good speed to every well considered effort to throw light on the archæology of Rome.

THE TIN TRADE.

From "The Mining Journal."

The very large deliveries of tin during the last few months are a certain indication of an extending demand, of a kind apparently uninfluenced by price. And thus the miner begins to ask why, if the present high price does not diminish the demand, a still higher one should not be obtained? In other words, why he should not get £175, or even £200, per ton for English refined, instead of £150? To

many the question may appear a bold one, whilst others will deprecate any further advance in price, because, forsooth, from a comparison of years, they consider the values now ruling extremely high. It must be admitted, indeed, that few, if any, can remember higher prices than those of to-day being paid for any length of time. An examination, however, of the present condition of the trade can but prove that the miners are not altogether faulty in their premises, or rash in anticipating what seems, indeed, to be more than probable.

No doubt the purchases for the continent, of tin and tin-plates have been exceptionally heavy; first, in consequence of the stoppage of all trade during the Franco-Prussian war; and, second, from the fear of an excessive duty on all raw produce imported into France. But there has been a cause far more important than either of these at work—the replenishment of the camp furniture of both of the contending hosts, and the re-furnishing of the desolated homes of France. It will take a long time to make up for what has been actually wasted, and meanwhile there is that steady onward march in the necessities of the human race. It is, however, unnecessary to dwell here on the incontrovertible fact that the demand for tin is steadily on the increase, since the deliveries, both from English and continental stocks, speak for themselves. But it is rather to the question of supply that we must turn as affecting the future price.

On referring back, we find that Straits tin was quoted on the 1st of this month £137 per ton; on Nov. 1, 1870, £127; and on Nov. 1, 1869, £123. Now, with such a marked increase of value, one would anticipate a very great and rapid increase in the supply; and yet what do we find?—that the actual quantity of this kind afloat for London and landing, was on the 1st of this month almost identical, certainly not 100 tons more than was afloat and landing on Nov. 1, 1870, when the price was £10 lower. A comparison between 1869 and 1870 would make this still more striking. From Straits tin we might turn to Billiton, and from Billiton to Banca, with exactly the same result—that the price, so far as these great centres of production are concerned, has been unable to stimulate the out-turn in any appreciable degree. Whether it is from want of labor we cannot say, but we may fairly conclude that, let the reasons be what they may, the islands of Banca and Billiton cannot be altogether, as some have reported them, of solid tinstone. Further investigations as to the other great tin-bearing centres of the world will still further demonstrate that high prices have failed to increase the production; in fact, in the case of the Bolivian mines, to which we are about to refer, we shall find that high prices tend rather to diminish than to augment the yield of the mines. Situated far inland from the Peruvian coast, these mines are worked almost solely by Indians and half-breeds, whose only object in labor is to earn sufficient for the bare necessaries of life, spending all that they are paid beyond that in feasts, often of weeks' duration. There is an undoubted abundance of tin there, but the unsettled state of the country, as well as the inhospitable region of the mines, are barriers hitherto too great for European enterprise. And until there is an organized system of labor from this country, there is little probability of our seeing a large import of Peruvian tin. Now, the above two great sources of supply are generally those spoken of when foreign tin is named. At the same time, to do justice to the subject, we must mention that Australia will be likely to send us some pretty fair quantities in the future; whilst nearer home, in Portugal, there are tin deposits almost "virgin." The little tin we have seen from this latter country is most excellent in quality, and the containing rock most promising in appearance; but as far as yet worked the veins do not appear sufficiently strong to justify the outlay requisite to bring any large quantity of tin into the market.

Let us now turn to Cornwall, one of the most ancient seats of tin mining known. There alone we see a response to the high prices now ruling. New mines are being started, and the old ones vigorously prosecuted. But it is a curious fact, that despite all her advantages, with an abundance of skilled labor, and large invested capital, there has been no sufficient augmentation in the yield of the mines either to flood the market or even to stay the upward move in price. Nor, indeed, have those who command her produce been as yet able to snatch from the hands of the importers of foreign tin the regulation of prices. The truth is, that, although there

have been new mines opened, no very large discoveries of tin have been lately made, and if it were not for the increased richness of some of the older mines, Cornwall would be in the same position as those other countries we have named.

There are several reasons why we may never expect a sudden glut from oversupply. First, no source has yet been found of a lasting kind which is not in the form of a vein. Now, to extract the tin ore from such veins requires a long time, powerful machinery if the mine be extensively worked, and great labor to get it out. Of course, important discoveries might be made any day, but even then it would take many of them to influence the present market much. Again, beyond the difficulties of mining tin, there will always be, as a drawback to any pouring in of that metal on the market, the difficulties of separating it from the containing rock before it is fit for smelting. This question of preparing tin for the smelter is one of very great importance, as affecting our present inquiry, since, from the mode of smelting, or rather reduction, as we may term it, of the tin stuff, otherwise oxide of tin, by means of carbon in the form of anthracite, it is necessary for the miner to render the mineral almost absolutely pure, it being practically impossible to separate in the process of smelting any large quantity of impurity. Scattered through the containing rock, as most tin ore is, the process of cleansing it is most difficult. First, it must be finely pulverized, then washed and washed again, then burnt and washed again, until its very collection is tedious in the extreme.

Those who have followed us thus far must, we think, readily admit that from the side of supply there is more to be said in favor of higher than of lower prices. It may be fairly urged on the other hand, that the present sources have more than amply supplied, in years gone by, as much tin as the world has required. Admitted that it was so, and further, allowing that the supplies are not less than in those times of glut, there still remains that ever increasing demand for all metals. In days gone by many cooking utensils were made of pure tin, whilst many were made of pure copper, but now they are almost all made of iron, with a thin film of tin to protect it, in other words, of tinplates. The tin required to make one of the old plates would now cover some dozens of cooking utensils; but the demand for the latter is in the proportion of 1,000 to 1 of what the former was. As we pointed out in an article on the Copper Trade in last week's Journal, vessels and utensils of tin-plate are fast superseding, even amongst semi-savage nations, the more showy and costly ones of copper. In India this is especially the case; and it only requires a spread of intelligence amongst the inhabitants of that vast territory, and what is, perhaps, equally important, a few lessons on the beauties of the interest table, to abandon what is costly for what is cheaper and equally durable. Such changes as we are now speaking of are the work of time, and cannot be effected rapidly; but that they are inevitable no one can doubt.

One last word on the effect of a rise of £10 in the value of tin on the cost of a tinplate saucepan. On referring to the quotations of the tin-plate makers, we find that a rise such as that we have named means an advance of 3s. on a box of tinplates. Query, how many saucepans can be made from one box of tin-plates? We are not tin-plate workers, but we think the equivalent advance in the value of each saucepan would be almost inappreciable. We are compelled thus to the conclusion that the demand for tin will be little, if at all, influenced by the price. We must not be misunderstood. We do not assert that the price of tin will be higher than it now is; we merely would point to those who are continually reducing all questions to precedent, how the market has stood without injury the repeated upward movements of the last few years.

Gold Standard in Germany.—It is intended that 1 lb. of pure gold shall be coined into 46½ pieces of 30 marks, 3 marks equal to 1 thaler, or into 93 pieces of 15 marks, or 69¾ pieces of 20 marks, the latter nearly equal to 1 sovereign, as they are almost of the same standard, 900 gold by 100 copper; or into 41 85-100th pieces of 30 marks, weighing 1 lb., and so on in proportion. It is provided that wear and tear is to be at the expense of the Imperial Government, an example it were vain to hope the English Government will follow.

WHAT SHOULD A ROAD LOCOMOTIVE WEIGH?

From "The Engineer."

We have excellent reasons for believing that there is a great future for steam on the highways of the civilized world. At this moment all the agricultural engineering firms who have constructed traction engines are deluged with inquiries as to the capabilities of these machines and the prices at which they can be supplied. It would be sheer waste of time and space to recapitulate facts concerning the work which has been done by such engines. It is now known as well as anything can be known, that in Great Britain and Ireland, in the United States, in South America, our colonies, India and throughout Europe it has been proved that steam power can be applied with advantage as a means of locomotion, wherever there is a fair approximation to a decent road. And with all this, and in spite of the success which has already attended on the exertions of inventors, it is certain that the traction engine is yet in its infancy. Before many years elapse it is probable that a very great trade will be done in the construction of road locomotives for all sorts of purposes; and the fact furnishes our excuse, if any is needed, for returning again and again to the subject. Complete believers as we are in the ultimate success of the system, we are not blind to existing defects as represented by the practice of various designers and manufacturers; and our duty to our readers, no less than our own inclination, demands that we should from time to time endeavor to aid, to warn, and advise those engaged in the construction of road locomotives. And we undertake this task in the light of an extended acquaintance with all the phases of existing practice, acquired during many years of patient observations, and with the certainty that we can speak, and think, and write with more impartiality on the subject than any individual who is practically engaged in making and selling machinery.

The most remarkable performance ever accomplished by any road engine is that of the Ravee in her double journey from Ipswich to Edinburgh and back. We have already given many particulars of the first half of this trip, and, thanks to the courtesy of Lieutenant Crompton, we are now able to place a complete tabular statement of the results of the entire trip, as a whole, before our readers. It will be found at page 357. We have already stated that, in our opinion, serious mistakes have been made in designing this and her sister engine, the most important error consisting in their excessive weight. The accuracy of our views on this subject has been impugned both in our own pages and elsewhere by those who hold different views, and we think that, with all the facts before us, it may be worth while to discuss the point here as to how far weight could or could not be reduced without impairing efficiency.

It is obvious that in approaching this subject it is simply impossible to express an opinion of any value as to what the engine ought or ought not to weigh, until we know exactly how much power it was necessary she should exert. Now it so happens that on this point Lieutenant Crompton is unable to supply any precise evidence acquired from indicator diagrams, nor are we aware that any attempt has ever been made to regularly indicate a traction engine on a long trip. We must therefore endeavor to get at the facts in another way. The experiments conducted at Wolverhampton last summer proved that Thomson engines developed 1-horse power indicated for every 33.3 to 37 lbs. of water evaporated. Making due allowance for the conditions under which the Ravee worked, we believe we shall not be far from the truth if we assume that the expenditure of each 34 lbs. of steam represented one indicated horse-power.. A glance at our table will show that the average consumption of steam—otherwise water—was 19.8 lbs. per ton per mile with the shoes on the wheel, and 14 lbs. per ton per mile without. Averaging these again, but making a small deduction for the fact that the shoes must, in regular service in countries where the roads are not always dry, be more frequently used than not, we have an ordinary consumption of 17 lbs. of steam per ton per mile. It is not very easy to get at a true corrected average of the speed of the Ravee, because of short stops for horses, which could not be accurately noted, but we

shall not be far astray if we take it at 7 miles an hour. Therefore, according to the data before us, the Ravee used per ton 3.5-horse power indicated to propel her at 7 miles per hour ; the gross load was 19 tons, and the engine must consequently have exerted 66.5 indicated horse-power. Going up hill, no doubt, this estimate was considerably exceeded, while in descending inclines it was reduced; but on the average of the whole journey our estimate is very near the truth, we believe.

A velocity of 7 miles an hour is 616 ft. per min.; 66.5-horse power is 2,194,500 foot-pounds ; dividing this latter number by the former we get 3,562.5 lbs. This represents the number of pounds gross resistance overcome by the engines at the given speed; dividing this by the number of tons in the load, 19, we have very nearly 187.5 lbs. per ton resistance. Now it appears absolutely impossible that on average roads, such as Lieut. Crompton ran over, the resistance could be anything like this. If he had run on soft gravel the whole time, the resistance would have been but 100 lbs. per ton, while on a good macadamized road it falls to 70 lbs. as a maximum. If we take it 100 lbs., which is excessive, it still follows that 87.5 per cent. of the useful work done by the engines was absorbed in overcoming their own resistance. There is no escape, from this conclusion, which, considering the great excellence of Messrs. Ransome's, Sim's, and Head's workmanship, is almost incredible, except we assume either that the engines did not really exert anything like 66.5-horse power, in which case the water must have left the boiler in the form of wet steam —we will not say priming ; or else that Lieut. Crompton is wrong in his estimate of the quantity of water actually used, which is, we think, out of the question, or, lastly, that the presence of Thomson tires on the engine and omnibus, increased the rolling resistance of the load to nearly double what it would have been without them.* It is not fair to bring in the influence of inclines, because in so long a journey the inclines must have balanced each other in effect, and the average resistance must have been just the same as though the engine had traversed a perfectly level—we do not say uneven—road. Let the facts be accounted for how they may, it still appears that it will sometimes be right to estimate the resistance which the engines of a high speed road steamer have to overcome at as much as 187.5 lbs. per ton, including their own friction, or 100 lbs. per ton for the resistance of the load alone, without engine friction.

The loaded omnibus hauled by the Ravee may be taken as weighing 5 tons. Let us put this as a representative or typical item, and assume that the average work required from any engine intended to perform the duties of the Ravee will consist in hauling 5 tons at 7 miles an hour average velocity. It follows from what we have said that this duty will be exposed by $616 \times 500 = 308{,}000$ foot-pounds of work per min.; this is 9.33-horse power. If the engine also weighed 5 tons, we should have sufficient power to propel both load and engine with 18.66-horse power ; and if we add about 50 per cent. for engine friction, the work might still be done for about 27-horse power. There is nothing assumed here, we think, that is not borne out by Lieut. Crompton's data, except the item of engine friction, and for this we allow an enormous margin. It will be objected that a traction engine, weighing 5 tons, would not be able to exert 27-horse power indicated, in the first place ; secondly, that it would not possess adhesion enough; and lastly, that it could not carry coal and water enough. The first point is easily settled by the results of experience. One of the little "steam sapper" class of engines, built by Messrs Aveling & Porter, weighing very little over 5 tons, gave out 40 indicated horse-power on the brake with ease at Wolverhampton in our presence. It is therefore certain that an engine weighing but 5 tons can be had which will give out 27-horse power. Indeed, the Field boiler of the Ravee, which, as we have seen, gives nearly 70-horse power, weighs but 2 tons, in spite of its enormous wood-burning fire-box. The objection on the score of adhesion may be settled as easily. A 5 ton engine may be depended upon to take itself and 10 tons up an incline of 1 in 20 in all weathers. No inclines can be met with on fair roads up which a 5-ton engine will not take a net load of 5 tons. We now come to the coal and water part of the question. The tank of the

* Lieut. Crompton does not state the consumption of water whilst standing under steam, but it must have been too small much to affect the results.

Ravee holds 365 gallons for, say, 66-horse power. Therefore, a tank somewhat over one-third of the capacity, or holding, say, 130 gallons, should suffice for the light engine. This weighs 1,300 lbs.—let us say 12 cwt. for water. The Ravee carries 1 ton of coal. The small engine would in the same way do with a little more than one-third the quantity. Coal and water would therefore weigh say 18 cwt., and so the gross weight of our engine would be 5 tons 18 cwt. Something must be added to this, however, because the foot plate must be enlarged as compared with an Aveling engine; but even if we allow a ton for this, and a moderate addition for the coal and water required for the transport of this additional ton, we still find that there is every reason to suppose that an engine can be made which, with coal and water for as long a run as the Ravee can perform without a stop, will weigh but 7 tons, or just one-half the weight of the Ravee.

We have yet two points to consider; the first is the argument that it is the great speed which must be occasionally maintained to make up an average speed of 7 miles an hour, which renders a heavy, or, in other words, a powerful engine necessary; the second point we shall refer to in a moment. Now we snbmit that the fact that a great speed must sometimes be maintained has little or nothing to do with the question. We have no evidence to show that the Ravee ever exerted for more than a few minutes at a time anything like 120-horse power; but even though we had, *cæteris paribus*, the facts would remain almost precisely the same for the 5-ton, or shall we say for the 7-ton, engine. She also could as well double her power for an effort as the Ravee could double hers. The true question at issue is the average power exerted by the engine on a trip of fair length, and if it can be shown that the resistance per ton is independent of the number of tons, and that the light engine can exert the same power per ton of gross load as her larger rival can exert, then any argument based on this question of speed falls to the ground. It must, in a word, be proved that the efficiency increases in a more rapid ratio than weight. But all existing experience with traction engines and road steamers goes to show that each reduction in the weight of an engine augments its relative efficiency. It is true that large engines and boilers make and use steam somewhat more economically than smaller boilers and engines, but there is also reason to think that the road resistance per ton increases with the weight in a very much more rapid ratio. On this score we do not think the advocates of the heavy system can make a single point.

The only remaining argument in favor of the heavy engine which we have now to consider is that the Thomson wheels weigh a great deal. There is some force in this. The india-rubber tires on the driving wheels of the Ravee, for instance, weigh each about 6 cwt. alone; but this difficulty may be got over to a great extent. In the first place, improvements may be made in the wheels by which they may be considerably lightened; and, in the second place, the breadth of tire for the light engine need not, other things being equal, exceed half that of the tires used in the Ravee. The driving-wheel tires of that engine carry nearly 10 tons, or 5 tons a wheel. The weight on both the wheels of the light engine we advocate would not exceed that on one wheel of the heavy engine. On the whole, we hold that our arguments in favor of a light engine cannot be defeated, unless, indeed, there are still some facts in the background which are known only to Lieut. Crompton and Mr. Thomson.

PETROLEUM EXPLOSION.—A serious explosion of petroleum on board a ship in the Thames took place this week. Vessels laden with petroleum are moored off Erith, and there were three of these vessels anchored near each other. An explosion took place on board the last arrived, and the vessel was at once wrapped in flames, which extended to the two others, but fortur ately the nearest one had discharged her cargo, and both were towed out of the way of farther harm. The men on board the vessel that exploded were severely hurt.

A NEW SHIP CANAL.—A subject of great importance to the mercantile and manufacturing communities of Liverpool and Manchester has recently been broached, viz., that of a new and independent canal between the two cities. The contemplated monopoly of the carrying trade in the hands of an amalgamated railway company gives additional interest to the suggestion for new means of intercommunication.

THE BEHAVIOR OF CEMENTS AND METALS IN CONJUNCTION.

From "The Builder."

In the course of the inquiry now going on as to the loss of the Megæra, repeated reference has been made to the use of brickwork and Portland cement in filling up between the ribs of iron vessels, and to the protection of iron by means of cement; and this has served to recall doubts we have long entertained as to the safety of bringing metals into conjunction with Portland and other cements.

At a meeting of the Institution of Civil Engineers in 1865, when Mr. Grant's first paper on "The Strength of Cement" was read, Mr. G. Dines, in the course of the discussion which followed, said he feared that Portland cement had a corrosive effect upon iron; therefore when cement had to be in contact with iron, he always used Roman.

Mr. Scott Russell, in reply to this, said Portland cement had been extensively used in the insides of ships to preserve the iron from corrosion; and after 18 years' use he had seen Portland cement dug out of an iron ship, when the red-lead paint and the skin of the iron were as sound as on the day they were put there.

Mr. H. Maudslay thought this fact appeared to show that the cement had not been in actual contact with the iron, as it was protected by the red-lead paint to the extent, probably, of 2 or 3 thick coats. The caution raised with reference to the effects of Portland cement in contact with wrought iron had been made upon the supposition of a fact which did not appear to exist.

Mr. Scott Russell suggested that the inference to be drawn from Mr. Maudslay's observation would be, that wherever cement was used with iron, the iron should be painted with red-lead.

Later in the discussion, Mr. F. J. Bramwell said, a question had been raised with respect to cement placed in contact with iron, which turned out to be a question of cement upon oil. He might say, that having occasion to form a deck upon a floating dock, which deck he did not wish to be combustible, so as to be in danger if a hot rivet fell upon it, nor to be liable to rot if temporarily immersed in water in a tropical climate, and which therefore did not admit of the use either of creosoted or of unprotected timber, he had made every inquiry he could as to the behavior of Portland cement concrete in contact with iron, and he was then having prepared a Portland cement deck, 3 in. thick; but he was afraid that experiment would not settle the question at issue, because, after all, it would only be cement upon oil; all the iron having been steeped in oil when hot.*

Soon after this discussion had taken place, a piece of stout iron piping was bedded part of its length in mortar-brickwork and the remainder in cement-brickwork; but whether it was Portland or Roman cement we are unable to state positively. Within the last two days we have examined the pipe, and find that where the cement was used the iron is destroyed and full of holes, while the other portion of the pipe remains as sound as it was at first.

We give this fact for what it is worth, and do not wish any general inferences to be hastily drawn from it. It may be that particular conditions are requisite to lead to this result, or that certain precautions will prevent it. At any rate, however, it inculcates the necessity for inquiry. Probably a special examination of one of our iron-clads in which cement has been used would not be out of place.

Touching the preservative power of a coat or two of red-lead, we should not be very sanguine, and for this reason. In a certain set of houses the external wall forms the back of the cistern, and the front and sides are of wood. The wall is rendered with Portland cement to form a flat surface; and the lead lining is dressed over cement and wood alike. We have recently examined several of these cisterns, and find that while the lead on the wood front and sides is perfectly sound and good, the lead on the cement has been entirely destroyed, and, indeed, is so changed in character that, from sight alone, it would be difficult to say what the material is.

These facts certainly show that further inquiry in the same direction is necessary, and should be instituted immediately.

* Mr. Grant's paper, with an abstract of the discussion issued by the Institution, forms a very valuable pamphlet. A report of "Further Experiments," by the same author, has been quite recently published, and is also valuable.

RANSOME'S PATENT STONE.

From "The Building News."

It is now a considerable time since we referred to Mr. Frederick Ransome's inventions, and to the toilsome progress by which he had reached a stage in the manufacture of silicious stone, a point at which we thought he might be well content to "rest and be thankful." We have found, however, from a visit to the works of the Company, at East Greenwich, that we were mistaken, and that Mr. Ransome, in the continued exercise of his characteristic perseverance, has personally, and in conjunction with other inventors, Mr. Henry Bessemer, Mr. J. W. Butler, and Mr. Pye Smith, chiefly, been pressing on to fresh triumphs.

It is not necessary to do more than briefly recall the important illustrations of the capabilities of Ransome's stone for decorative purposes, as exemplified in the great capitals of the University, in the Grecian style, recently erected at Calcutta; in the ornate fountain playing in the public gardens at Hong Kong; in the screens, designed by Sir Digby Wyatt, of the Indian Court, Whitehall; in the balusters, vases, and other ornamental "repeats" of S. Thomas's Hospital; and in numerous other situations. The more recent applications of the principles of Mr. Ransome's invention are to useful rather than to decorative purposes, but in this direction and for the material applied to structural purposes, new and important inventions have also been made and patents for them secured.

Strange though it may seem, it is none the less true, that from the production of a material that only an expert can tell is not real Portland stone, inventive skill has passed on to produce admirable imitations of red and gray granite, and porphyritic rocks of all kinds, including their large crystals of felspar; black, gray, Sienna, and other kinds of marble, veined and mottled in the structure, with a truthfulness to nature that it would baffle the skill of the most accomplished "grainer" to surpass. These interesting specimens are shown with truly-worked mouldings, and a glassy polished surface, equal to productions in the natural rocks.

A further improvement in manufacture, or rather an additional application of the patent stone, relates to the production of stone caissons for sea and river walls, piers, etc., and other hydraulic works. In this application of the material, Mr. Ransome is associated with Mr. J. W. Butler, hydraulic engineer. One of these caissons has recently been sunk, with complete success, at the entrance to the London Docks. It is 35 ft. deep, and passes from the bed of the river down into the London clay. The cylinder is in sections of about 4 ft. deep; they are 9 ft. in diameter and 8 in. thick, and have tongued joints. The whole caisson was sunk with ease in the course of two days.

The works connected with structures that are founded under water are of two distinct classes, the preliminary and the permanent, both of which are very costly. The preliminary works include sheet piles, coffer-dams, iron caissons, and the like, which may be superseded by these stone caissons, that are of a material of great strength, and adapted to serve as permanent piers and abutments. When sunk, they have only to be kept clear of water by pumping, and filled up with concrete, brickwork, or other material. The materials and process of manufacture of these caissons are totally different from those of Mr. Ransome's former method. The ingredients include, in the proportions found best, ordinary large sharp-grained sand, or even fine gravel, hydraulic cement, ground carbonate of lime, soluble silica, with an adequate quantity of Mr. Ransome's silicate of soda. In this combination the silicate of soda is decomposed, the silicic acid combining with the silicate of alumina and the caustic lime of the Portland cement. The caustic soda thus set free has an affinity for, and combines with, the soluble silica of the mass, producing again more silicate of soda, which is again attracted and converted, until the whole is utilized and completely fixed. The stone is hard, strong, and dense, and admirably adapted to resist the influences of heat, cold, water, or moisture. As regards its strength, it may be enough to say that it is proved to resist crushing force up to 4 tons, or 8,960 lbs., on the square inch. Granite resists to from 8,000 to 12,000 lbs., Bramley Fall to 5,120

lbs., Portland stone to 2,630 lbs., and wrought iron to from 36,000 to 40,000 lbs.

The grindstones manufactured at East Greenwich, in vast numbers and of all sizes, are not now a novelty; but our readers will probably be "surprised to hear" that large numbers of these stones are constantly sent to the great engineering works at and near Newcastle, where they cost more money than the native article which is there at home. It is an old saw that "Scotsmen and Newcastle grindstones are found all over the world." The proverb may continue true of Scotsmen, who are to be met with in every clime, and particularly on the green spots on the earth's surface, but it is ceasing to be true of Newcastle grindstones. The new patent article is now sent in great numbers to the colonies and foreign countries, and it is not to be wondered at that it is preferred to the natural stone; it is perfectly homogeneous, cuts more keenly, wears quite evenly, and has no yolks.

Another utilitarian purpose to which Ransome's invention is now applied is to the production of millstones for grinding wheat, rice, and other grains. The ingredients in these differ but slightly from those that are mixed for the production of grindstones. Care is exercised in the selection of hard sharp sand, with good cutting power, and in fabric the mass is harder than in the case of the grindstones. The millstone is moulded with grooves as deep as it will be safe to wear the stone. These are filled up to flush with the upper part of the stone with Portland cement, plaster of Paris, or other material softer than the stone. In use, these grooves wear to a sufficient depth to permit the flour to escape in the ordinary manner. If these stones can even do as much work, and as well, as the French burrs or granite millstones hitherto in use, it is palpable that they must possess immense advantages. They have now been in constant use in Brussels and other places for many months, and the *ascertained* advantages realized from their use are: lower first cost, they are driven with less power, do more work, and require no dressing or disturbance until they are worn down to the bottom of the channels. There is another advantage secured by the use of these stones, but *it is only a question of life and death.* The men who dress and fit the blocks of which the French burr stones are built, never live to be older than 32 or 33 years, and the dressers of burrs, at work, sustain proportionate injury from that part of their occupation. They are all choked and poisoned with the dust of flint and steel. From inevitable death, as a result of their occupation, there is no escape. The economical aspect of the question may be the most important in the estimation of some jolly millers, but it may be hoped, surely, that all will be ready to take in the humanitarian view, if only as a make-weight.

Another of the novelties to be seen at East Greenwich Stone Works, is the manufacture of discs for saw sharpening and other uses. These are of various sizes and thicknesses, from one-eighth of an inch thick upwards. The chief ingredients in their composition are emery and silicate of alumina. The pugged material is packed into a strongly made iron mould, into which a die is fitted, and the material is pressed by a hydraulic ram, exercising a pressure of 70 tons. The discs are dried and hardened either with or without artificial heat. The performance of these emery discs is surprising. Their keen cutting power is to be seen at the works, East Greenwich, and also at the works of Messrs. Allen, Ransome & Co., King's-road, Chelsea. Some of these discs have been in constant use daily at a large saw mill, and at the end of three months are not nearly worn out. One of these discs, ¼ in. thick, will attack a saw blade an eighth of an inch thick and cut it at the rate of 6 in. per minute! This valuable substance —emery—is found in large quantities in various parts of the world, as at Naxos, in the Archipelago, Spain, Poland, Jersey, Turkey, Austria, Smyrna, Minnesota (United States), etc. It is of the nature of corundum or adamantine spar, but really consists of the flinty shells of deposited masses of animalculæ. It seems likely that these emery discs will come into extensive use for many purposes to which they are capable of being applied, in addition to saw sharpening, and not unlikely that they may exercise an important influence upon file cutting and file using.

The works of the Ransome Stone Company and East Greenwich are well worthy a visit by any one interested in construction and cognate arts.

PATENT FUEL.

From "Engineering."

"Take 3 parts of the best Newcastle coal beaten small, 1 part of loame, mix these well together into a masse with water, make thereof balls, which you must dry very well. This fire is durable, sweet, not offensive by reason of the smoke or cinder as other coal fires are, beautiful in shape, and not so costly as other fire, burns as well in a chamber even as charcoal." The foregoing extract, taken from a fragment of an old book supposed to have been printed about the year 1670 or 1679, and headed "An excellent Invention to make a Fire," contains probably the earliest reference on record to the manufacture of what is now commonly known as artificial, or patent fuel. At that date, however, very different reasons existed for preferring such a fuel to coal in its natural state, to those which now prevail, as an inducement to its manufacture. When coal was first introdured into London, the greatest possible objections were raised against it, and the manufacture of the compound fuel above described is evidence of the strong prejudice then entertained to the use of coal. In the life of Mr. Locke, we are told (1679) that the Earl of Shaftesbury required Mr. Locke to return to London. "He accordingly returned thither, but not being wholly recovered, and finding himself afflicted with the asthma, he could not tarry long at London, the sea coal that is burnt there being so very offensive to him." Poor Mr. Locke! But it may reasonably be asked, what would be his feelings now, could he pay a visit to his former haunts in London upon a foggy November day? Fortunately, we inhabitants of this great metropolis, in the 19th century, have become so far acclimatized, as to be not only above complaining of such trifles as coal smoke, but most of us even wish that the fuel could be obtained more cheaply, so that we might burn more of it. The question then at the present day, which concerns the manufacture of patent fuel, is not one of prejudice, but of necessity; for the waste of our coal resources has at last assumed such gigantic proportions as to have attracted the attention of the Legislature, and no one studying the interesting reports of the late Coal Commission can fail to be struck with the enormous national loss which is now annually endured owing to the want of some efficient means for the economical utilization of the small coal which is now unavoidably made even under the very best known systems of coal working. Probably it would not be in excess of the fact to assert, that fully one-third of the coal now hewn is reduced to that state wherein it becomes known as "small," "slack," or "duff," and not more than two-thirds becomes ultimately burnt in the shape of "round" coal. The small produced in bituminous coal seams will coke well, and it is much used for that purpose; but the demand for coke not being in any way equal to the supply of bituminous small coal from which it might be made, a great proportion of the latter is left underground, and ultimately becomes lost beyond all possibility of future recovery. The small from steam coal will not coke; and hence it is, as a rule, almost invariably left below, as it would not pay to raise it to the surface so long as there is no market for it, and it could only be thrown on one side in a heap, occupying ground which might be better and more conveniently used for other purposes. With the extended manufacture of patent fuel—which at present appears to offer the only means of profitably utilizing small coal to any great extent—not only would a market be provided for small coal which now unavoidably collects at the pit's mouth, but if carried on upon a sufficiently extensive scale, it would afford sufficient inducements to the colliery proprietor to bring up all the small coal that could be raised, together with the round coal. At present this manufacture may be said to be quite in its infancy, and it employs only a very minute proportion of the small unavoidably made at comparatively few collieries, and its results in this respect are wholly unappreciable excepting at a few pits in the immediate vicinity of the manufacture. Thus there is room, as there is also an urgent necessity, for the establishment of works of this nature throughout the length and breadth of the kingdom wherever coal is to be found; moreover, it is quite possible that patent fuel may, from its utilization of small coal, render it possible at some future time, to

work seams with profit, which either from their softness and friability, or for other reasons, are now looked upon as worthless.

The first patent taken out for the manufacture of patent fuel was in December, 1799, by one John Frederick Chabannes, but it is probable that the process described above as having been adopted 120 years previously, had in the meantime undergone some improvement. According to this invention, small coal was to be consolidated by mixing it with "earth, clay, cow dung, tar, pitch, broken glass, sulphur, sawdust, oil-cakes, tan, or wood, or any other combustible ingredient, to be mixed together and ground with a wheel in water in a wooden vessel; the mixture is then to be placed in pits provided with drains for the water to run off, and when dry is to be moulded into cakes." Impracticable as the process above described must have been, it no doubt served as a basis upon which many similar patents have been subsequently drawn up. The next invention, dated May 20, 1800, was for putting small coal, together with certain other ingredients, into an oven or kilns, causing the several particles to unite together by fusion; a system which, upon experiment, must have been found to be utterly impracticable. The first really practicable system suggested for the manufacture of patent fuel was one patented by Peter Davey, in 1821, which is the first time that any proposal appears to have been made to form the mixture into blocks by pressing it into moulds. Between that time and now—that is to say, during the last 50 years—the question of patent fuel manufacture has been steadily growing year by year into greater importance, and many are the names of those who have given their attention to the matter. If the mere fact of taking out patents had been sufficient to induce the manufacture of any article in proportionate quantities, we should not now have to complain of the millions of tons of small coal which are being annually wasted. For one reason or another, this manufacture has not kept pace with the requirements of the times, owing probably to this fact, as much as to anything else, that the various patentees in this field of enterprise knew very little about the real merits of the question, desiring rather to see others carry their suggestions into practice than to risk any money upon them themselves. The few patent fuel manufactories that now exist, are upon a small scale only, and are little better than private enterprises, although some of them rejoice in the title of "company." What is really wanted is a company in which a sufficiency of capital for the carrying out of the manufacture on a large scale, is combined with a practical knowledge of the subject by all to whom its interests are confided. As a proof of the total want of the last named qualification in certain instances, it may be mentioned, that among the most common errors of would-be fuel manufacturers, is the one that, by mere mechanical combination of materials, results may be obtained equivalent to a chemical change in the ingredients themselves; thus that, by the mixture of anthracite and bituminous coals, a fuel may be obtained corresponding in its properties to steam, or semi-bituminous, coal; or, that by mixing a very good and a very poor coal together a fuel of a fair average quality may be obtained. Nothing could be further from the truth, for by no means can mere mechanical combination alter the nature of the several ingredients used. In a fuel thus made with a mixture of coals, each particle will burn in the precise manner, and give the results due to the peculiar seam from which it was taken; whilst the pitch, tar, or other medium used for combining the small particles together will, in like manner, give out the flame, heat, or smoke due to its combustion under similar circumstances when not forming part of a block of artificial fuel.

Owing to the convenience of stowage, and that patent fuel occupies much less space per ton than coal in its natural state, the former is chiefly in demand for shipping purposes, and the small coal used is almost exclusively that from the steam collieries. The principal seat of its manufacture is in South Wales, whence steam coal is shipped chiefly for foreign ports; but there is no apparent reason why this manufacture should be so confined to one spot, when it would be equally beneficial in the vicinity of all our coalfields throughout the United Kingdom. For whatever purpose coal from any colliery is used, patent fuel made from the dust of such coal should find a ready market, with this reservation only, that it must be borne in

mind that a process of manufacture suitable for steam purposes will not always be applicable to fuel for domestic use, but the converse will not equally hold good, for any process that will produce the latter kind of fuel should be equally good if applied to steam coal. In most of the patent fuel manufactures for shipment for steam purposes an excess of bituminous matter is introduced, either as pitch or tar, which not only would be objectionable to the senses, if used for domestic purposes, but it would require a greater draught in order to secure proper combustion, and consequent freedom from smoke than is usually obtained in domestic fireplaces.

WOOL AND ITS IMPURITIES.*

From "The Mechanics' Magazine."

If it sufficed for the necessities of the divers industries dependent on wool that the carded wool of commerce should be of good color, its fibres smooth, clean, and parallel, we might congratulate ourselves on the progress made of late years in wool carding. But, unhappily, it is altogether different, when we come to consider the same wools with regard to their absolute industrial values; that is to say, their aptitude for taking dyes and their suitability for spinning and dressing. The great majority of wools used at Roubaix are but imperfectly purified from the earthy and fatty matters which they naturally contain, and from those with which they become contaminated in the process of carding, either accidentally, or to facilitate the operation. Now, these impurities are the essential cause of numerous imperfections in each of the subsequent operations, and, if not removed, perfection is impossible, either in dressing, spinning, or dyeing.

Conditioning.—This first operation has for its object to ascertain by absolute dessication the true weight of wool in any bale. Samples are taken from the bulk of the cleansed and carded wool, of which it is desired to know the degree of humidity, and carefully weighed; they are then submitted to a temperature of 105 to 108 deg. By this means the water they contain is evaporated, and, on reweighing, the absolute weight is supposed to be obtained. If the wools were really pure, this mode of ascertaining the value of the wools would be very rapid and sufficiently exact; but it is a matter of fact that all substances dissolved in a liquid hinder its evaporation and elevate its boiling point, and the influence thus exerted becomes greater, with increase of the affinity of the liquid for the substance in solution.

Amongst the most common impurities of carded wool are to be found: Salts of lime, derived from the water in which the wools are washed, and which form, with the oils of the wool and with the soap used, insoluble soaps, which add to the weight and deteriorate the wool, rendering it dusty and greasy; soap, and the substances used to adulterate it; starch, kaolin, resinous matters, silicate of potassa, etc., animal moisture, and glycerine, all increasing the boiling point of water; so that the effect produced on wool by heating to a temperature of 105 deg. is proportionate to its degree of purity, and in no way to the amount of moisture which it contains. Under these circumstances it is useless to deduct the amount of moisture evaporated and estimate the remainder as so much pure wool, since it really contains salts of lime, insoluble soaps, glycerine, etc., which hold water with a tenacity incapable of being ruptured at 105 deg. With this state of things *conditioning* will never be anything but an empty word—an illusion.

Dyeing.—Good dyeing is not possible, unless the wool has previously been thoroughly purified from all fatty matters, and from animal moisture. Bleaching—that is to say, this thorough cleansing and purification—therefore, constitutes an integral part of dyeing, and it is of the utmost importance that it should be most efficiently carried out; in fact the dyer should watch this part of the process constantly.

The next point to be attended to is mordanting. Nearly all the colors used in dyeing require, in order to form a stable dye, that they should have for their base, some metallic substance, the bodies used

* A paper read before the Association of Commerce at Roubaix, by M. Vasson.

for this purpose being the mordants. Now, if the compounds formed between the coloring matters and the dyes are insoluble, the compounds formed between the mordants and many of the impurities in the wool—the soap in badly-washed wool for instance—are not less fixed and insoluble. If the mordant be a salt of iron, for example, it forms an insoluble iron soap which effectually prevents the wool from taking a good pure tone of color. In order to get a good result under such conditions, dyers are constantly in the habit of evading the obstacle, and dyeing without any mordant whatever; so that mismanaged cleansing gives rise to fraudulent dyeing, colors thus put on being merely superficial and valueless.

NITROGEN IN NATURE AND ART.

From "The American Exchange and Review."

The aqueous ocean which covers nearly three quarters of the area of our globe, and which performs so essential a part in the economy of nature, from its peculiar characteristics presents features of the greatest interest to the student of physical science. Not less interesting, however, and of far greater amplitude, covering both sea and land, is that vast aerial ocean, extending into the regions of space, and known as the atmosphere, in which we live, and move, and have our being. This immense expanse of mingled gases, which presses upon the surface of the earth with a gravity equal to that of a solid sphere of lead nearly 6¼ miles in diameter rises to an altitude the exact limit of which is still a matter of doubt, but which, from calculations based upon the phenomena of refraction, is usually assumed to be about 45 miles, although more recent observations upon the zodiacal light and meteoric showers, indicate that it may extend to a height of upwards of 200 miles. This voluminous mixture, which in the ancient system of philosophy was considered an elementary body, affords a constant field of study, both in its physical and chemical aspects; and in each of these specific divisions it has received the attention of eminent investigators, who have gradually added to the knowledge we possess of its properties.

As is generally known, the atmosphere is a mechanical mixture of two gases—nitrogen and oxygen—together with minute quantities of carbonic acid, and aqueous vapor, and traces of nitric acid, ammonia, and hydrocarbons. This composition is remarkably uniform. Air from the delta of the Nile, from the arid plains of Egypt, from the icy cliffs of Mount Blanc, from the snow-clad summit of Chimborazo, from an elevation of from 18,000 to 21,000 ft., gathered by means of balloons, and from the lowest levels of deep mines, has been subjected to careful analysis, and but a trifling variation from a uniform composition has been detected. For all practical purposes, atmospheric air may be considered as simply a mixture of nitrogen and oxygen; its other constituents—chiefly derived from local sources—existing as impurities. Of these gases, nitrogen largely preponderates, comprising ⅘ of its bulk.

Notwithstanding the many causes combining to vitiate the atmosphere, this balance is beautifully maintained. When we take into consideration the fact that at every inspiration we inhale into the lungs a certain proportion of oxygen, which there combines with carbon, and is exhaled as carbonic acid, it is apparent that a heavy draught is being constantly made upon the vitalizing principle of the air, which is replaced by a poisonous impurity. The amount of carbonic acid thus daily generated from the lungs of a single healthy adult is not less than from 33 to 40 oz. When this amount is multiplied by the population of the world, and the product of the respiration of the lower animals added, together with the immense quantities of carbonic acid produced by combustion, putrefaction, and fermentation, it will be observed that vast streams of impurities are being constantly poured into the air and diffused throughout its volume. And yet, with all this pollution, so active are the energies of nature, and so harmoniously are her processes performed, that under the influence of solar rays plants take up the carbonic acid, and by the mysterious operations of their development decompose it into carbon and

oxygen, retaining the former to build up their structure, while eliminating the oxygen to once more resume its active vocation in the air.

Nitrogen, which plays so important a role among the elements, was discovered in 1772, by Dr. Rutherford, Professor of Botany in the University of Edinburgh. He demonstrated that air from which oxygen had been abstracted by the respiration of an animal, and the resulting carbonic acid absorbed by lime water, still contained a gas incapable of supporting either respiration or combustion. Lavoisier and Scheele subsequently proved that this gas constituted $\frac{4}{5}$ of the air. The former of these chemists gave it the name azote, from two Greek words signifying privative of life, by which it is still known in France. Chaptal afterwards named it nitrogen, because it enters into the composition of nitre.

The properties of nitrogen gas may be described by a series of negatives. Singularly inert in its habitudes, and capable of directly entering into combination with but few of the other elements under the influence of light or an elevated temperature, its office in the air seems to be simply that of a diluent of oxygen. Some chemists have supposed the atmosphere to be a chemical compound of these two gases; but this opinion is entirely fallacious. The mixture is merely a mechanical one. Oxygen is essential to life, and to every process, either natural or artificial, in which we are interested. Did the atmosphere consist wholly of this gas, or should it occur in much larger proportion than its normal quantity, the effect on animals would be almost equally disastrous, as would result from an undue diminution of its percentage. The processes of life would be stimulated and quickened to an unnatural extent, and this would be followed by a speedy exhaustion and death. Nitrogen, by its negative chemical qualities preserves the physical balance between the elements of the air, and fits it for the admirable functions which, in the all-wise purposes of creation, have been delegated to it.

With hydrogen, nitrogen forms the useful volatile alkali known as ammonia, its name having been derived from that of its chloride—sal ammoniac—which was largely produced by burning camel's dung in the Lybian desert, near the temple of Jupiter Ammon. This important compound was known to the alchemists, having been mentioned by Raymond Lully as early as the 13th century. Traces of ammonia are found in the air, in soils, and in some mineral waters. It is a product of the putrefaction and decay of animal and vegetable tissues, and is largely eliminated from coal during the process of manufacturing illuminating gas. The latter is now the most important source of the ammoniacal salts of commerce. Ammonia is one of the most useful and important reagents in the laboratory of the chemist. In medicine and the arts it is largely employed. In the economy of the household its carbonate is sometimes used in baking, and at the same time it is an appliance of the toilet in the form of "smelling salts." Its sulphate is a constituent of alum, in which form its application to the arts of dyeing and calico printing is very extensive. Its chloride likewise ministers to the requirements of industry, while its nitrate has within a few years become an article of extensive business as a source of nitrous oxide, an anæsthetic which, in minor operations, has proved a boon to thousands of patients.

Of the oxygen compounds of nitrogen, nitric acid and its salts are the most important. This powerful acid is one of the most highly corrosive bodies known. The readiness with which it parts with its oxygen is one of its most valuable features, and leads to its extensive application in the arts as an oxidizing agent; while its salts, which in certain combinations possess this property in a high degree, are endowed by it with an importance which renders them indispensable in every civilized community. So long as war is regarded as the ultimate resort of contending nations, will the salts of nitric acid maintain their prestige as conservators of power. In this aspect they demand a recognition beyond that usually accorded to chemical compounds, and enforce their claims to the attention of statesmen with an urgency which experience has fully justified. As a constituent of gunpowder, nitrate of potassa preëminently asserts its demands upon the requirements of governments; and as other nitrates may be converted into this salt, they all possess a significance which renders their fabrication worthy of grave deliberation.

The phenomenon of combustion is simply a process of rapid oxidation. When this process is accelerated beyond the capabilities furnished by atmospheric oxygen—in other words, when oxygen in a condensed form is furnished to a combustible—it results in deflagration. If the deflagration takes place in a confined space, explosion is the consequence. The proper control and utilization of the pent-up energies of explosive compounds has formed a subject of momentous importance, coexistent, almost, with the progress of civilization; and, as in all of the combinations which experience has proved reliable, nitrogen in union with other elements plays a significant part, a discussion of their origin and properties may not be unprofitable.

Probably the earliest known compound of nitrogen was nitrate of potassa, which was mentioned in the 8th century by Geber as *sal petrae* (rock salt)—whence the term saltpetre; but, of course, in this remote period not the slightest knowledge of its composition was entertained, as this was first determined by Cavendish in 1785. Even prior to this time, saltpetre must have been practically known to the Chinese; for, at the inception of the Christian era, this remarkable people were well acquainted with fireworks, into the composition of which nitrate of potassa largely entered. The peculiar characteristics of this salt eminently adapt it to the manufacture of gunpowder; but before entering into a discussion of its merits, it will be well to inquire into the nature of other nitrogen compounds, and to glance at their relative qualifications.

Nitric acid, according to the heretofore received theories of chemical nomenclature, consists of one equivalent of nitrogen combined with five equivalents of oxygen; or, in percentage, amounts (omitting fractions) of 26 parts of nitrogen with 74 parts of oxygen. As its value in combination consists solely in the amount of available oxygen it will yield, those of its salts having bases of a low combining power would seem best fitted to exhibit its value, for the reason that they furnish a relatively larger proportion of this powerful supporter of combustion. For example, the bases magnesia, lime, and soda, all possess a lower combining power than potassa, the proportions being as 20 : 28 : 31; while potassa possesses the comparatively high equivalent of 47. Thus, while nitrate of magnesia contains nearly 65 per cent. of oxygen; nitrate of lime, 58.53 per cent.; and nitrate of soda 56.47 per cent.—nitrate of potassa contains but 47.52 per cent.; and yet from its physical qualities the latter salt possesses advantages which overcome the higher proportions of oxygen which the others yield. With the single exception of nitrate of potassa, the nitrates above mentioned are too deliquescent in their nature to adapt them for use in the manufacture of gunpowder. Nitrate of potassa, on the contrary, does not abstract moisture from the air; and hence gunpowder made from it may be kept for an indefinite period with its qualities unimpaired.

Although the composition of gunpowder is generally understood, it may be well in this connection to revert to its constituent parts. in order to inquire into the influence its nitrogenous component exerts in its action. The proportions of its three ingredients—charcoal, sulphur, and saltpetre—vary in a trifling degree, as the product may be required for artillery, blasting, or for sporting purposes. Theoretically, the requirements of gunpowder determine that the proportion of its constituents should be one equivalent of saltpetre, one of sulphur, and three of carbon, which, reduced to percentage amounts, would be 74.9 parts of saltpetre, 11.8 parts of sulphur, and 13.3 parts of charcoal. On the ignition of this mixture, nearly 60 per cent. of its solid constituents instantaneously fly to the gaseous state, thereby enormously expanding in bulk—1 volume of the powder becoming suddenly augmented to 296 volumes. Nor is this all; for in the sudden conversion of the carbon into carbonic acid, which is accomplished by the disengagement of the nitrogen and oxygen, and the appropriation of the latter by the carbon, an intense heat is generated, which vastly expands the resulting gases, increasing their bulk to more than 1,500 times the original volume of the powder. The wonderful energy of this explosive may thus be seen at a glance. Before its resistless force potentates have fallen and thrones have tottered; and with a universal recognition of its power, governments have sought to control its sources, and have resorted to all conceivable means to insure its coöperation in

their varied schemes of conquest, aggrandizement, or defence.

Of the constituents of gunpowder, charcoal and sulphur are abundant, and may be produced in almost all countries. Saltpetre, however, is a substance whose occurrence in any noteworthy quantity is restricted to limited localities, mostly far remote from those centres where it is needed for use. Of its component parts, potash is produced wherever wood is burned for fuel, and hence a supply of this constituent may be readily obtained; but its nitric acid, which is its ultimate source of power, must be sought for in the few localities in which it exists in the form of nitrates, for by treatment with wood ashes or salts of potassa these nitrates may all be converted into nitrate of potassa —in which form alone, as we have seen, is a nitrogen compound fitted for use as a constituent of gunpowder.

In the provinces of Bahar, Bengal, Allahabad, Agra, and Oude, in India, near the banks of the river Ganges, exists the most remarkable deposit of nitrate of potassa in the world. Extending along the valley of the sacred stream for a distance of several hundred miles, this salt is found as an efflorescence or crust upon the surface of the sandy soil, where it occurs mingled with small quantities of the nitrates of soda and lime. The surface soil is removed and lixiviated in water, and the crude solution evaporated to the point of crystallization, when the small impure prismatic crystals of commercial saltpetre are deposited. In this form it is largely exported, the average annual production being estimated at about 25,000 tons. The British Government wholly controls this source of saltpetre, and for reasons of its own has twice prohibited its exportation —the latter time during the Crimean war —thus suddenly producing a great scarcity, and rapidly enchancing the price of what was already in the market. In China, Ceylon, and other parts of Asia, there are caves and plains where nitrous earth is found ; but they bear no comparison with the remarkable deposit of the valley of the Ganges.

In South America, on the borders of the republics of Peru and Chili, within a few miles of the town of Iquique, there exists a deposit of nitrate of soda—sometimes known as soda saltpetre—which is scarcely less remarkable than the beds of its potash congener of the Ganges. This deposit has been proved to extend for upwards of 150 miles in length, and is from 2 to 3 ft. thick. As it is dug from the ground it consists of upwards of 60 per cent. of nitrate of soda. It undergoes a hurried purification by lixiviation and crystallization, and is then largely exported to this country and Europe, where it is extensively used in the manufacture of nitric and sulphuric acids, as well as in the fabrication of nitrate of potassa. Other deposits of soda saltpetre of considerable extent exist in parts of Brazil. In the United States there are caves in various parts of the West, where nitrous earth abounds, from which saltpetre is manufactured. In Kentucky, Tennessee, and Missouri, considerable attention has been paid to the subject, and under proper management this branch of industry might, perhaps, be prosecuted with reasonable success.

The preparation of nitrate of potassa from nitrate of soda is a very simple art. It was formerly performed by adding equivalent proportions of a solution of nitrate of soda to a boiling solution of the ordinary potash of commerce, when a change of bases resulted, the product being nitrate of potassa on the one hand, and a mixture of carbonate of soda, together with some caustic soda, on the other, as the potash used may have been more or less carbonated. Since the large importation of muriate of potash from the Strassfurt salt mines, this compound, owing to its greater cheapness, has been substituted for commercial potash. In this case the product is nitrate of potassa and chloride of sodium, which latter is sometimes sold as "chemical salt" for fertilizing purposes.

In addition to these sources of nitrates, the natural production of nitrous compounds is imitated by artificial saltpetre plantations, in which advantage is taken of the peculiar results of the decomposition of animal matters. These refuse materials, which contain a varying proportion of nitrogen, in the process of gradual decay generate notable quantities of nitric acid, which combines with lime, potash, or any other available base which may be present. By the addition of wood ashes the whole of these nitrates may be converted into nitrate of potassa. In this manner saltpetre is made in France, Germany, Hungary, and other European coun-

tries. The process, however, is a very slow one, and the product small; and in the event of a sudden and unexpected demand, it must be regarded as incapable of furnishing a sufficient supply.

The limitation of natural beds of saltpetre to but few localities, and the extreme slowness with which nitrates may be artificially produced, together with the fact that its natural stores are held by nations which may perhaps in time be hostile to us—these considerations open up grave questions as to our supply in such a contingency as may readily happen. Modern warfare is not decided merely by the relative bravery of contending armies, or the military skill of eminent generals. National power depends much more closely upon the unlimited possession and control of resources indispensable to the prosecution of war and the sustentation of large forces, and chief among these requirements is an exhaustless store of ammunition. As we have seen, we can furnish within our own borders an abundance of all the constituents of gunpowder, with the single exception of its nitrous component. For this essential we are almost wholly dependent upon foreign countries.

We have hitherto referred to gunpowder only as a source of power in war; but in the arts of peace and in the prosecution of daily industry it claims our attention as one of the most efficient appliances ever invented by the skill of man. In the vast engineering works which distinguish modern times from earlier periods of history, explosive compounds have borne a great share of the burden, and have contributed in a ratio beyond that for which credit has been given. In the construction of railroads and canals, in the quarrying of rocks and minerals, in the extraction of ores from their hidden recesses deep in the ground, in the blasting of tunnels and levelling of mountain masses, in the deepening of channels and watercourses, gunpowder has performed its useful functions and asserted its power as one of the most useful energies which has been subdued to our requirements.

Nor is it to gunpowder alone that we are indebted for this great assistance in overcoming the impediments of nature. Other explosives are now extensively used, and in nearly all of them we find nitrogen an essential element. In gun-cotton, which, in the hands of the Austrians, has been successfully applied to artillery; in the newer, but far more terrible compound, nitro-glycerine; in dynamite and dualin, the singularly inert nitrogen plays its peculiar part, and by the very feebleness of its affinities and the ease with which it leaves its fetters and resumes its gaseous state, endows its mixtures with a terrific force, which, properly controlled, has proved of inestimable benefit to civilization. But even these explosives are surpassed in violence by other compounds of nitrogen. The fulminates of silver, mercury, and gold all contain this element, and to its presence is their fearful detonating power ascribed; while, ascending still higher in the scale of violence, we find the climax reached in the action of the chloride, bromide, and iodide of nitrogen. These unstable bodies can be made only in exceedingly limited quantities in the laboratory of the chemist. So readily and with such terrific force do they explode, that they are almost entirely beyond control; and even with a full recognition of what obstacles science has hitherto overcome, it is safe to assert that these compounds can never be subdued to the uses of man.

If we pursue our inquiries into the realms of nature and investigate the composition of the members of the animal and vegetable kingdoms, we shall find nitrogen one of the most important elements entering into the formation of their tissues. The agriculturist practically recognizes this fact by supplying to crops under culture fertilizers in which nitrogenous compounds form a prominent feature. All our important cereals and leguminous plants which constitute staple articles of food in various climes, derive much of their value from this source. Indeed, dietetic materials have been divided by some physiologists into two classes—flesh formers and heat producers. The former division, which builds up and renews our bones, blood, muscles, and tissues, being largely composed of nitrogenous substances; while the latter, which serve by their oxidation to maintain bodily warmth, consist chiefly of starch, oil, gums, etc., into the composition of which nitrogen does not enter. Deprived of nitrogenous food, emasculation would succeed the once vigorous condition of the body, and a rapid declension of vital power would ensue, terminating in certain dissolution.

The nitrogenous remains of the brute creation, which are unfit for food, are made subservient to our uses in a variety of ways; and guided by the teachings of chemistry, which is the great conservator of economy among the sciences, almost every fragment is utilized and turned to a profitable account. Even that which escapes our attention or care, by the revivifying processes of nature, is soon eliminated from its former combinations, and fitted to enter anew into the composition of plants and animals, to again minister to our wants.

In the form of cyanogen and its compounds, nitrogen enters into another series of combinations of great importance in the arts. In the deadly prussic acid, in the golden and ruby crystals of the prussiates of potash, and in the azure pigment known as prussian blue, it is an essential constituent. Again we find it occurring in the beautiful tinctorial products of the aniline series of colors—as mauve, magenta, rosaniline, and their congeners.

The vegetable alkaloids, which in the hands of the skilled physician have so often assuaged pain, removed disease, and brought back the ruddy glow of health to the pallid cheek, invariably contain nitrogen; and so significant a position does this element hold in their composition that from its presence have chemists always started in their speculations upon the constitution of these important bodies. Among this class may be mentioned the deadly poisons, nicotine, strychnine, morphine, brucine, coniine, and the like, whose fearful effects upon the system are frequently invoked by the suicide, and employed by the cowardly assassin.

And thus, in these various mutations, we find the inert nitrogen fulfilling its functions in nature and art. Surrounding us on all sides by its perpetual presence, and yet perceptible to our senses only when wafted in gentle breezes, or in the more forcible aerial currents known as winds; preserving us from the too exhilarating effects of oxygen by toning down, as it were, its stimulating qualities; aiding to build up our bodies, and to repair the wasting muscles and tissues, and furnishing us with delicate pleasures of the table; and again gently lulling us to slumber, and guarding us from pain when the aid of the surgeon must be invoked, we can but gratefully appreciate its mission and recognize its value. In other forms, helping us to fight our battles and to defend our borders from invasion; assisting in our national celebrations in pyrotechnic displays; building our railways and levelling our rugged and precipitous mountain passes; blasting our ores and minerals from their rocky veins; and anon dealing death and destruction by accidental explosions, its mighty power compels respect and claims the homage due to resistless force. Again, in its compounds supplying us with tints rivalling the hues of the rainbow or the glories of the setting sun; furnishing us with costly furs and silks, and woollen raiment of more modest pretensions, ministering to our requirements in the hour of disease by providing remedies indispensable to the medical profession, and yet presenting the suicide with his deadly potion, its influence for good or evil is of no ordinary degree. Although at times indifferent and apparently incapable of positive character, yet among the elements it occupies a position of great importance, fraught with interest to all living beings.

THE GLOBE ENGIRDLED.

From "The Mechanics' Magazine."

In the history of applied science there is nothing more marvellous than the development of Telegraphy. Whether it be by overhead or subterranean land lines or by submarine cables; whether we regard the manufacture of the conducting wires (of which we had a recent notice) or the invention of instruments for transmitting and recording massages,—it is surprising to reflect upon the giant strides that have been taken since the first submarine cable was laid across the English Channel, some 20 or 25 years ago.

It is within a generation that Telegraphy has risen into note as a special science and profession, and at last received due

recognition by the establishment of a Society of Telegraph Engineers, as announced by us last week.

At the present moment all that is needed actually to complete a "girdle round the globe," such as Shakespeare only dreamt of, is the connection of the American Pacific Coast and the Islands of Japan; which link in the circumterranean communication is now in contemplation. Mr. Cyrus Field, of Atlantic Cable celebrity, has projected a line from Victoria, the capital of Vancouver's Island, to Hakodadi, in Japan, and from thence to the Russian naval station on the coast of Asia, whence, across the steppes of Siberia, the telegraphic wire penetrates to St. Petersburg, and is united with the European system. This new line, the estimated length of which is 4,370 nautical miles, will touch at Atcha, one of the Aleutian Islands.

The second route projected by Mr. Field, is identical with the first, as far as Atcha; it pursues a more southerly course to Yokohama—a distance from the United States of 4,235 miles. From Yokohama it describes a segment of a circle to Shanghai—a further distance of 1,010 miles. A branch crosses the Island of Niphon and the Japan Sea, and joins the Russian lines at Possiette. A third and last route starts from San Francisco, traverses the North Pacific to Honolulu in the Sandwich Islands, connects this group with Midway Island, and thence to Yokohama—a total distance of 5,573 miles. Making an allowance of 20 per cent. for slack, the length of cable required for the first route is 5,244 miles; for the second, 5,244; for the third, 8,463. Each line is supposed to terminate at Possiette, which is 1,480 miles from Yokohama. It is in contemplation to lay a cable between Honolulu and the Australian Colonies, thereby establishing direct intercourse between Melbourne and San Francisco. This line is thus divided:—San Francisco to Honolulu, 2,093 nautical miles; Honolulu to Fiji Islands, 2,950; Fiji to New Caledonia, 810; New Caledonia to Brisbane, 800—6,653; add 20 per cent. for slack, 1,331; length of cable, 7,984 nautical miles. Brisbane is already connected by land lines with Sydney, Melbourne, and Adelaide; also with Port Darwin on the north coast, from which place a line to Java is under contract for construction. The Dutch colony is now in direct relation with the India and Chinese cables. These being completed, however, it would be vain to imagine that in 40 min. a message would encircle the globe. Allowance must be made for breaks, as the wires are by no means continuous, but for which less than 40 secs. would suffice.

FIELD ARTILLERY.

From "The Engineer."

A report has just been printed by the War Office containing a summary of the proceedings of the Committee on "High-Angle and Vertical Fire from Rifled Howitzers and Mortars," and on "Muzzle-loading Rifled Guns of Large Calibre for Field Service." The report in question is made with reference to the 16-pounder gun, now recommended for the Service by this committee. It would be difficult to name a subject, connected with artillery matters, of greater importance. In the field, whatever may be the value of the work performed by individual batteries, the decisive effects are produced by massing guns; and for this purpose pieces of heavy calibre are retained in reserve, and are kept in hand for the moment when their fire may be brought to bear on an important point with crushing and decisive effect. The 16-pounder, then, is the gun that must strike the telling artillery blows in our future battles. It behooves us to weigh well any decision governing the power and character of such an arm. The report before us commences by relating the preliminary steps that brought the Committee to the final aspect of the question. They were, it seems, informed that "the great object in view was to ascertain and lay down definitely what should be the weight and calibre of the largest class of rifled guns suitable for field service." Certain existing bronze guns—9-pounder smooth bores, of 13 cwt. and 10 cwt.—were placed at the disposal of the Committee, which guns they converted into rifled 20-pounder howitzers;

these gave, as might be expected, unsatistory results; 20 lbs. was the minimum weight of projectile which would give good proportions with so large a bore as that of the 9-pounder smooth bore, viz., 4 in., after conversion; and 20 lbs. was too heavy to admit of the required mobility. Then the metal appeared to be too soft. The axis of the trunnions fell below that of the bore, and there was great preponderance in these guns; all these caused difficulties that warranted their condemnation. A proposition was made by Major Palliser to line them, and at the same time to reduce their calibre and improve their proportions; but so much alteration was required that it appeared unlikely that there would be such a saving of expense as to justify the adoption of a patched gun, or a new carriage, in preference to a new gun altogether. The Committee, therefore, recommended the manufacture of 2 guns, of a weight of from 11½ cwt. to 12 cwt., with a preponderance not exceeding 10 lbs.; "that their calibre should be between 3.5 in. and 3.7 in., whichever might be found best suited to a shrapnel shell weighing from 16 lbs. to 17 lbs., and a common shell about 3 calibres in length;" that the rifling should have a uniform pitch of 1 turn in 30 calibres, and that the service charge should be 3 lbs. On the 17th of January, 1871, accordingly, trial was made of a gun, whose weight was 11 cwt. 2 qrs. 21 lbs., its calibre was 3.6 in., and its preponderance 10 lbs. Its shrapnel weighed 16 lbs. 5¾oz., and its common shell was 10.25 in. long. It conformed, in fact, with the required conditions, and this gun in all essentials corresponds with that finally recommended for adoption into the service. An important question, however, arose, before this conclusion was arrived at. "The attention of the Committee was drawn to the advantage of a 3.3 in. bore for a 16-pounder gun, for which bore, it was contended, a projectile might be constructed capable of sustaining velocity longer than any other projectile of the same weight" —and we must assume of the 3.6 in. calibre. Comparing the projectiles of the 2 calibres as to their powers of flight, it appeared that, supposing them both to start with an initial velocity of 1,350ft., their remaining velocities at 1,000 yards would be 1,052 ft. per second for the smaller, and 1,020 for the larger calibre; and at 2,000 yards range their respective velocities would be 920 ft. and 889 ft. per second. So it was agreed to make a trial of a gun of 3.3 in. calibre as it was found that the useful capacity of the shrapnel shell would not be materially affected by the decrease of diameter, and the twist of 1 in 25 was given to this gun.

The two guns then "were tried at Shoeburyness, both having the same length of bore, and both being rear vented. It was found that the reduced calibre gave an increase in length of 2 in. to the cartridge, and interfered with the rapidity of ignition of the powder, so that the initial velocity of the 3.3 in. gun was only 1,307 ft., against 1,358 ft. obtained with the 3.6 in. gun. Fired at 2 deg. of elevation, the smaller calibre ranged 1,057 yards, the larger 1,187. At 9 deg., the smaller 2,172, and the larger 2,228; but fired at 10 deg. elevation the projectile of the former gun had succeeded in overtaking that of the latter, obtaining at this elevation a range of 3,619, against 3,596." The powder employed throughout was that known as service R.L.G. The accuracy of the two guns was about the same. The 3.6 in. bore was therefore recommended.

This all seems so sound, so reasonable, that the conclusion appears almost foregone before the end of the trial. Nevertheless, after all the experiments that have been made during the last few years on the resistance experienced by projectiles in flight, the apparent insignificance in the effect of the difference of calibre between 3.3 in. and 3.6 in. seems strange, and calls for close scrutiny. The weights of the shells are equal, and the resistances are in the proportion of 1,089 against 1,296 at any given velocity. In examining the report more carefully, the first question that arises is, "Why do the Committee *estimate by comparative velocities* at various points, and then, instead of reporting as to this, change their ground, and give the *ranges due to various elevations?*" This seems to obscure rather than to clear up the matter. "It was contended," they say, "that the smaller bore was capable of sustaining its velocity longer." The contender was, at all events, right so far, for it is absolutely impossible that this could fail to be true. The Committee, however, urge that the length of the cartridge of the smaller bore prevented rapid ignition of the powder, so that

the projectile started with a lower velocity. Venting at the rear was all against the small bore; but assuming this was necessary, why is no more said of velocity? It is hard enough to be handicapped, but then to have attention called to the relative positions at starting, as though it were the finish, is indeed adding insult to injury. Having noticed the velocity that told against the small bore, not one word more is said on the subject; the key is changed, and we only hear of ranges due to various elevations, as if the contender had said that the smaller calibre would have a higher *initial* velocity.

But it may be asked, if two projectiles leave their guns at the same angle of elevation, does it not follow that the one that obtains the greatest range has, on the whole, travelled the fastest, since they both must fall at the same pace? Certainly it has travelled the fastest on the whole, but here lies the pith of the question. Is it the object that the shell should travel as fast as possible, or that *it should hit as hard as possible?* It may be that the 3.6 in. shell starting faster is not "overtaken"—this seems to be the Committee's conception—by the shell of smaller calibre, but if the latter has *commenced to overtake it*, if, in fact, though still behind it on its path, its velocity is greater, it strikes a harder blow, the weight of the 2 shells being equal. Surely 2 or 3 in. in the height of the trajectory can hardly make up for this. If we accept, then, the initial velocity furnished by the Committee themselves, will our readers believe—calculating by means of the tables drawn up by Professor Bashforth—it appears, even at the end of a 1,000 yards range that the remaining velocities stand 1,031 ft. per second for the smaller calibre, against 1,020 ft. for the larger? That is, the former shell has done what was "contended"—it has sustained its velocity so much better than its rival that, even starting at a considerable disadvantage, it is already moving the faster of the two, and will strike the harder blow. It has, in fact, commenced to overtake the larger shell. At 1,500 yards the respective velocities are 958 ft. against 939 ft.; at 2,000 yards they are 902 ft. against 877 ft.; and at 2,300 yards, 872 ft. against 844 ft.; the shell of smaller calibre continually increasing in power as compared with the other. But the Committee may say, it is still behind it. Let us try to look at the matter, then, from this point of view. Is it the great object to get in the shot as *quickly* as possible? If two men fight, one may be the stronger, but his adversary may get his blow in first; he may, in short, give him a black eye before he has time to strike. We find the shell of larger calibre may, at a certain range, perhaps strike the object .02 of a second sooner than its rival, and its path may be an inch or 2 lower in the air. If this is the argument, we ought indeed to insist on our gunners being trained to drill with rapidity. If the decimal part of a second in the *date of arrival* of a projectile is of such pre-eminent importance, it is sad to reflect how many times .02 of a second may be lost by a cough, almost by a wink.

To return to the trajectories of the shells. It appears that at 3,000 yards and over, the tables are turned, for here, we are informed, the one of smaller calibre *has* "*overtaken*" its rival, and won the race. No great stress seems laid on this circumstance, the range being a long one, only 500 yards short of 2 miles. But we must recollect that we are discussing reserve artillery, in which range and power at long ranges are of primary consequence. The fact is, we are now coming to the most important ground on which the smaller calibre might claim that advantage. Reserve artillery strike the decisive blows in battle; in almost all cases the guns are brought up and called upon to open fire, in the teeth of, at all events, some pieces already in action. This is a service that may be one of great difficulty and danger. General Okouneff, the most enthusiastic advocate for massing guns, considers that it is impossible for batteries to come into action under the fire of a really powerful artillery with a hope of success. Surely under these circumstances it is difficult to insist too strongly on reserve artillery having a superiority in range, and in power at long ranges, over light or ordinary field batteries. Suppose the order given to bring up the reserve guns for a decisive movement. Every 50 yards the batteries advance they become subject to a great augmentation of casualties, not only because during such an advance they are exposed, and are liable to be crippled or checked, but because they are coming under a fire which is growing each moment more powerful, and which,

as yet, they have not answered; because they may be traversing ground over which the enemy have been, as it were, practising, and of which they know the range of every spot, and because every 50 yards they have to move increases the difficulty of opening fire simultaneously, and generally necessitates the batteries closing on each other laterally. Here, then, the stand is to be made. The 16-pounder, of 3.6 in. calibre, can hardly be said to be superior in range to the field batteries already in the service; nay, it remains to be shown that it is at all superior in this respect to the Armstrong 12-pounder, which has so long been our field battery gun, for though the projectile of the 3.6 in. gun has a higher initial velocity, the resistance of the air acts with more power on it, so that the 12-pounder may even have the greater range at the higher angles of elevation.

It is curious, however, that the Committee have conceded one advantage that might have been urged in favor of the 3.6 in. bore as compared with the 3.3 in. bore viz., that the shell must have the superiority in interior capacity, from the fact that it is more compact in its form than its mere elongated rival. This ought to tell both on the number of bullets contained in its shrapnel and in the bursting charge of its common shell. It seems, however, from the report, that this is not very manifest, probably from the fact that the bullets happen to be of a size fitting with less loss of space in the shell of smaller calibre. On the other hand, we cannot but believe that had any extended trial been made at long ranges, the smaller calibre would have proved its superiority in accuracy in flight.

Altogether, we would express a hope that, since the 3.3 in. gun has achieved what was contended for it, that since it has proved itself superior in all respects at long ranges, and superior in striking velocity at 1,000 yards and over, that it will not be condemned because at the shorter ranges it has a "date of arrival" of a small decimal part of a second greater than its rival, or because its trajectory is, under these circumstances, 2 in. or 3 in. higher.

MR. WHELPLEY'S THEORY OF GRAVITATION OR CONSTANT FORCE.

By W. L. MARCY.

The assumption of Jas. D. Whelpley in the December No. that the distance fallen through is proportional to the square of the actuating force is erroneous. Whelpley's error is in regarding, with different forces, the spaces fallen through, equal when the velocities attained are equal.

Thus, if 1 oz. falls free, it descends 16 ft. in a sec., but distributed over 16 oz. as in the Atwood machine, there is a descent of 1 ft. in a sec.: but it does not follow that the 16 oz. falling free with an actuating force 16 times as great as when urge l by 1 oz. will in $\frac{1}{16}$ of a sec. fall 1 ft., for, as recognized in the "Essay," the distance of the fall is proportional to the time squared; hence, instead of 1 ft. in the $\frac{1}{16}$ of a sec. it is $(\frac{1}{16})^2 \times 16 = \frac{1}{16}$ of a ft., although in both cases the velocity is the same at the end of the sec. with 1 oz. force and $\frac{1}{16}$ of a sec. with the 16 oz. force, but the distances fallen through are inversely as the forces. Again, the 1 oz. force will, at the end of 4 sec. fall $(4^2 \times 1)$ 16 ft., giving a resulting velocity of 8 ft. instead of 32, for, the velocity in all cases varies as the time multiplied into the actuating force.

In Whelpley's example, a body actuated by one unit of force falls 1 ft. in a sec., acquiring a velocity of 2 ft. per sec. Now these units of force will give the same velocity in $\frac{1}{3}$ of a sec., but the fall is $\frac{1}{9}$ of a ft. instead of 1 ft.; here lies the error by which he arrives at a result of 9 ft. in a sec. which should have been only 3 ft. in that time.

The error of the assumption can be readily shown theoretically by regarding the constant actuating force as so many regular impulses infinite in number, describing spaces in arithmetical progression. Calling the first space d, we have from the equality of the impulses the series $a + 2a + 3a + \ldots . na$ (V) in which the sum

expresses the distance of the fall and the last term the resulting velocity. By the known laws of such series the square of the last term, nf (equivalent to the velocity) or of the number of terms, n (equivalent to the time), is proportional to the sum or distance of the fall, which accords with experience. Furthermore, we infer from the same series, that the last term or velocity may be equal, but the sum or distance fallen through unequal, for the sum of the series for a given final term (V) is inversely as the impulse d, or actuating force.

STRAINS ON ARCHES.

From "Engineering."

The author, after adverting to his method* of constructing a curve of equilibrium for an arch unequally loaded with continuous or discontinuous weights, or under oblique pressures, proceeded to apply it to the determination of the stresses on rigid arches and other curved structures.

As the consideration of an arch of masonry was more simple than that of a rigid arch, a preliminary illustration was given by an examination of the Pont-y-tu-Prydd, an arch of small stability, with the peculiarity that its spandrels were constructed with cylindrical openings. The effect of these openings was described. To show the nature of the change of the curve of equilibrium by oblique pressure of the backing, this curve was drawn on the supposition that the backing was a perfect fluid, pressing at right angles to the back of the arch. The action of a passing load in increasing the stress upon the masonry was also examined.

The stresses of a rigid arch had hitherto been a subject of considerable difficulty, owing to the intricate nature of the mathematical analysis it was necessary to employ, and the labor of applying formulæ to trace the variation of stress from point to point was considerable. Still, before the transverse sections of arch ribs could be proportioned to the stresses coming upon them, a knowledge of this variation was indispensable.

The main object of the paper was to show that the stresses at every point of an arch rib could be determined by a diagram, and that some questions, such as where the form of the rib was neither circular nor parabolic, and when the pressure was oblique, which would be almost intractable by analysis, could be readily solved. The curve of equilibrium being the locus of the resultant of all the outward forces, the bending moment was the pressure in the direction of the curve multiplied by the perpendicular upon the tangent. The curve having been determined, the stress caused by the bending moment could be ascertained, and this, added to the uniform compression, was the total stress at any point. By shifting vertically the positions of the points of the curve at the crown and springing, the stress could be indefinitely varied, and the curve could be made to satisfy the conditions of the rigid arch or invariable span, or the rigid arch with the ends fixed.

These conditions were then investigated and gave the following results. The neutral line of the arch rib having been divided into equal parts, and the bending moments at each of these parts obtained from the curve of equilibrium, when the ends were fixed the sum of all the bending moments had to be made equal to zero; when the rib was of invariable span, the sum of the bending moments, each multiplied by the vertical ordinate of the point to which it corresponded, had to be made equal to zero; and when the ends were fixed and the rib of invariable span, the above conditions had both to be satisfied. When the section of the rib changed from point to point, each bending moment was to be divided by the moment of inertia of the cross section corresponding to it, before entering it in the summation. It was then remarked that where the curve of equilibrium touched the surface of the rib, the compressive stress was doubled, trebled, or quadrupled, according as the section was I or box-shaped, tubular, or of the form of a solid rectangle. For vertical forces only, the bending moment at any point was equal

* Abstract of a paper read before the Institution of Civil Engineers, London, by Mr. Wm. Boll, C. E.

to the horizontal thrust multiplied by the length of the vertical line between the curve of the rib and the curve of equilibrium.

A mathematical investigation was entered into for a circular rib, considered as a voussoir arch, or rigid arch with the ends fixed, in a similar manner to Mr. Airy's treatment of the circular rib of invariable span. It was shown that the stresses could be equally well ascertained by diagram as by mathematical investigation. When a moving load was the only force acting on an arch rib, the curve of equilibrium was two straight lines, meeting in an apex vertically above the load. As the load moved, the locus of this apex depended on the condition of the rib, as to whether it was rigid, or in the state of a voussoir arch. The action of a uniformly distributed load was then examined, and the circular rib compared with the parabolic. It was remarked that a straight or curved girder might be considered as an arch of any rise, but without horizontal thrust, and it was shown that, by drawing any curve of equilibrium for the weights, continuous or discontinuous, acting on the girder, considering it as an arch, the stress at any point was the horizontal thrust multiplied by the vertical ordinate.

The action of oblique forces was then entered into, and the case of the curved gates of the Victoria Docks was examined.

The stresses on the elliptical caissons used in the foundation of the Thames Embankment were next ascertained by construction. It appeared that when the eccentricity of an ellipse under normal pressure was small, the curve of equilibrium was nearly a circle, whose radius was the mean between the length of the major and minor semi-axes of the ellipse; and that if a boiler, which was an arch in tension instead of in compression, were not truly cylindrical there would be considerable transverse in addition to the tangential stress, and if the deviation from an exact circle were greatest at the riveted joints, the stress would be greatest at the weakest parts. It was then remarked that at an ordinary lap joint, or at a part where the deviation of form amounted only to half the thickness of the plating, the stress at the surface of the iron was four times that due to the uniform pressure of the steam. This result, which showed how greatly a boiler might be weakened by an imperfection of form too slight to be detected by the eye, was not, in the author's opinion, generally known. There could be little doubt that incorrectness of form, the evidence of which was destroyed when a boiler exploded, was one of the chief causes, and hitherto an unsuspected cause, of many of the boiler explosions which occurred from time to time throughout the country.

The last example chosen was the somewhat complex case of the roof of the St. Pancras Station, Midland Railway. The form of the rib differed from the circle and parabola, the section varied to some extent near the springing, and as the action of the wind on the roof was considered, the question was also one of oblique forces. The curves of equilibrium for the roof, acted on only by its own weight, were first drawn. For the actual condition of the rib, namely, that of a rigid arch with the ends fixed, the curve was contained everywhere within the depth of the rib. For a pressure of wind of 40 lbs. per sq. ft., the curve showed two maximum stresses of 4.08 tons and 4.14 tons per sq. in.

The arch rib had been treated as of invariable span, but real or virtual alterations of span might be caused by changes of temperature, a yielding of the abutments, and the compressibility of the arch rib itself. It became then an important practical question to determine, for wrought-iron arches, how much the stresses might be altered by a small alteration of the span. The method of ascertaining this generally was then described, and it was found that a wrought-iron rib of 200 ft. span, 20 ft. rise, of an I or box-shaped section, and loaded uniformly, might have the stress at the crown increased from 4 tons to 6¼ tons per sq. in. This would happen if the abutments each yielded ½ in. under the thrust, and the temperature were reduced 60 deg. below that at which the parts of the rib were put together. This result included the stress caused by the compressibility of the iron.

In order to draw the elastic curve of the rib, it was then shown how to find the displacements of the different points, by change of temperature, compressibility of

the metal, and action of the bending moment. The deflection of the crown was the alteration of the rise of the rib as found by this process. Applying it to the case of the rib of the St. Pancras Station roof, the deflection of the crown was found to be .2 in., while observation had given from $\frac{3}{16}$ to $\frac{1}{4}$ in., so that the agreement of calculation with observation was very close.

The author proposed to measure stresses by direct observation of the extension or compression of a small length of the material of a structure. For a stress of $\frac{1}{5}$ ton per sq. in., the extension of a length of 50 in. of wrought iron was $\frac{1}{1000}$ of an inch, which, if magnified 50 times, would be read as $\frac{1}{20}$ of an inch by the eye. During the testing of a structure, two microscopes, magnifying 50 diameters, with scales in their eye pieces, fixed about 50 in. apart, would measure stresses of $\frac{1}{5}$ of a ton per sq. in. in the most direct manner, and the stresses could be measured at the critical points of a structure.

The author thought that this method of observation might even be useful in another way; if, as was probable, inferior kinds of wrought iron approached to cast iron in the scale of their extensibility under moderate stresses. By taking an observation the stress could be accurately determined by calculation, the quality of the iron which had been used in a structure might be ascertained.

HEATING FEED-WATER.

From "The Engineer."

Much ingenuity has been exhibited by numerous inventors in designing apparatus for heating feed-water, but an examination of most of the schemes proposed for effecting this purpose will prove that a great deal of ignorance exists as to the conditions to be fulfilled before success in the highest sense of the word can be commanded. The general principles involved are very simple. A pound of steam at atmospheric pressure, 14.68757 lbs. on the sq. in., the barometer standing at 29.9218 in., and the temperature being 212 deg., contains 1146.6 units of heat, each unit representing the quantity of heat required to raise 1 lb of water 1 deg. Fahr. Any feed-heating apparatus worked by the exhaust steam from the engine can only raise the feed-water to the temperature proper to the barometric pressure at the time being, provided the engine is of the non-condensing class. This temperature is universally taken for convenience as 212 deg. If the ordinary temperature of feed-water were zero, then the whole advantage that could be derived from a heating apparatus would be represented by $\frac{1146.6}{212} = 5.408$, or 17.54 per cent. But it is a physical impossibility to have feed-water at zero, and we have given the preceding figures to show that the maximum theoretical saving to be effected by raising the temperature to 212 deg. is 17.54 per cent. The normal temperature of feed-water in Great Britain may be taken at 57 deg., and this temperature must be used, consequently, as the basis of any calculations intended to determine the maximum economical result to be expected from a feed-heater. Deducting 57 deg. from 212 deg. we have 155 deg. The best feed-heater, therefore, working by waste steam, can save but 155 units of heat out of 1146.6, or 13.4 per cent. We have heard it urged by men who ought to know better, that, although this may be true of a boiler working at or about atmospheric pressure —much as Watt's earlier engines did—it is not true of a boiler working at, say, 50 lbs. on the sq. in., because the whole heat contained in 1 lb. of steam of that pressure is taken to be 915.58 only; and that, as a consequence, the calculation stands $\frac{915.68}{212} = 23$ per cent. But these gentlemen forget that the water has to be heated after it enters the boiler by the difference between 212 deg. and 251 deg. The total number of units of heat in 1 lb. of steam of a total pressure of 50 lbs. on the sq. in. is, in fact, 1167.99 deg., so that the saving effected by the use of a feed-water heater is actually reduced as the boiler pressure increases. It is not our purpose here to describe minutely specific forms of heating apparatus, but to deal with the principles on which they operate; and we shall consequently do no

more than allude to the fact that the simplest, and therefore best, way to heat feed-water, when a non-condensing engine is used, consists in blowing a portion of the waste steam back into the tank from which the feed-pump draws. If this tank is suitably arranged, and the influx of cold water is constantly maintained at one end while the feed-pump draws from the other at a higher level, no difficulty will be experienced in raising the temperature very nearly to the boiling point. The excessive simplicity of such an apparatus is no small recommendation to its use; and we find this principle now adopted by nearly all makers of portable engines—a hose being led back from the exhaust pipe to the water bucket or tank. By this simple device some 8 per cent. or 10 per cent. of the fuel is usually saved.

We have now to deal with a totally different class of feed-heaters—to wit, those used with condensing engines. The feed-water drawn from hot wells usually has a temperature of 100 deg. to 120 deg.—say, 100 deg., and therefore the saving to be effected by raising the temperature to 212 deg.—as has been proposed by making the feed-water circulate round a long eduction pipe extending from the valve chest to the condenser—could only amount to about 9.7 per cent., even if the temperature of the exhaust steam was that proper to the terminal pressure of the cylinder, which it is not, as the instant the exhaust port is opened it falls in well made engines to the temperature proper to the condenser, or nearly so. Feed-heaters, used in connection with condensing engines, always operate, therefore, through the agency of the waste heat passing from the boiler flues; and it is very difficult, for reasons which we shall now explain, to contrive a really satisfactory heater operating in this way. We have found by experiment that in a good Cornish boiler the gases at the end of the flue, when just leaving the boiler, had an average temperature of 400 deg., the boiler pressure being 50 lbs. above the atmosphere, corresponding to a temperature of 297 deg. Fahr., and this may, within certain limits, be taken as representing good stationary engine practice, when the boilers are properly set and the draught is not forced. Now, in round numbers, we may assume that to bring the feed-water to the temperature of that in the boiler $\frac{1}{5}$ of the whole quantity of heat required to convert each pound of water into steam must be supplied in the heater. If the heater were as efficient, foot for foot, as the boiler, it would follow that it must even then have one-fifth of the whole heating surface of the boiler. The efficiency of any given area of heating surface depends, for one thing, on the difference between the temperatures at opposite sides of the plates, and we think it quite unnecessary to enter into any calculations to prove that the efficiency of a square foot of boiler surface must be very much greater than a square foot of heating surface. This being true, it follows that the heater, to be efficient, must have much more than one-fifth of the surface of the boiler; and if this fact was generally borne in mind we should hear less than we do of the extravagant claims put forward by some makers of heating apparatus, who assert that they can save 20 and even 25 per cent. of fuel by the aid of heaters which do not present one-twentieth of the heating surface of the boiler. It is true that some boilers are so badly proportioned, or so improperly set, or fired so hard, that an immense amount of heat is wasted up the chimney, and in such cases even a small heater will do good, and probably save much fuel. But with properly set and designed boilers the heating apparatus must present a very large surface, certainly not less than $\frac{1}{4}$ that in the boiler, if the feed is to be raised much above 212 deg.; but any heater so constructed that it will take up from waste gas, already lowered to a temperature of 400 or 450 deg., enough heat to raise the temperature of the feed to that of the boiler, will effect a very considerable saving. Let us say, for example, that the boiler temperature is 300 deg., corresponding to a total pressure of 67 lbs.; then the saving effected by heating the feed-water to 300 deg., instead of injecting it at 57 deg., will be represented by $\frac{1173.4}{234}$ = 4.82, or 20.7 per cent.

The moment we attempt to construct such an apparatus we find ourselves beset with troubles. In order to obtain enough surface within a moderate space, the heater must consist of some arrangement by which the water is cut up into filaments or streams. Therefore, all these heaters, or "Fuel Economizers" as they are some-

times called, consist of some arrangement of tubes, vertical, horizontal, spiral, or inclined. These tubes, and the parts connected with them, must be competent to withstand the boiler pressure, and this they can be made to do without much difficulty. The great obstacle to their use, however, lies in the fact that they cannot be kept clean without special and more or less complex devices. It is easy enough to get rid of the soot which is freely deposited on the outside of the tubes, and various arrangements of continuously working wire brushes, scrapers, etc., have been patented for this purpose, some of which are in use; but it is next to impossible to get rid of the deposit within the tubes.

The salts of lime and magnesia, held in solution in most waters, are freely thrown down the moment the water is heated above 212 deg., and the consequence is that the pipes rapidly become furred up and inoperative. If they remain sufficiently open to suffer the feed-water to pass through them, it is only because the incrustation is so thick that the water is no longer made hot enough to throw down any deposit.

It must not be forgotten, however, that this very difficulty may be made to work for good. If the deposit takes place in the heater, then it cannot take place in the boiler. What is wanted is a heater, to be used in connection with stationary boilers, which will work as a separator as well, from which every particle of deposit can be easily removed from week to week. Such an apparatus could not fail to be popular in the highest degree, and we believe that it can be produced. In its production, however, lies a neat problem, which we beg to commend to the attention of our readers.

TRAMWAYS AND THEIR STRUCTURE, VEHICLES, HAULAGE, AND USES.*

By W. BRIDGES ADAMS, Esq.

From "Journal of the Society of Arts."

It is now approaching a period of two years since I read in this room a paper on tramways, endeavoring to foreshadow therein the shortcomings of their proposed system, and pointing out the requirements needed. The desirability of their becoming State and municipal property was shown, together with misgivings as to any State origination, and the possibility that private companies, in the then condition of commercial ethics and governmental perceptions, would, on the whole, be a necessity, and might induce the smallest amount of waste with the greatest profit to both the community and the companies.

So far, the tramways have now been delivered over to companies, trammelled with conditions which will probably end in arbitrations, if at some future time it be found that the disputes between companies involve public inconvenience and inefficient service. As a commercial question, it is quite clear that directors must study the largest profit for their shareholders, and that they will only give in return for it as much service to the public as will prevent traffic from falling off. If a given sum is to be made annually, it will be less trouble to obtain it by a small traffic than by a large one, where no competition exists.

The tramways are popular, and, if we analyze the sources of their popularity, we find them to be threefold. First, greatly increased space for sitting and moving in the vehicles; secondly, a greater freedom from oscillation; thirdly, the larger number of passengers provided for—preventing disappointment in getting places. But, to set against these, there is the great waste and cost of haulage, not lessened but increased by the substitution of the rail for the pavement. The effect that should arise from the more even surface is neutralized by the grooves in which the wheel flanges travel; and the total resistance to traction is double that of the ordinary railway, on which the flanges of the wheels bear against only one surface with lateral freedom, while on the tram

* A paper read before the Society of Arts.

they bear on two surfaces, and act almost as a constant break, as may be verified by the sound while riding, and the incessant vibration while in motion. There is no doubt that the ordinary omnibus, with its flexible construction, runs far more freely on the stones as regards traction, than does the tramway car on the rails; and when we come to the modern asphalt surface, which gets rid of the omnibus oscillation, the ease of movement reduces the resistance to traction nearly to the minimum. Were the interior of the omnibus as convenient as the tramway car, there is no doubt that it would be preferred.

But the rail has an advantage which the asphalt has not—automatic guidance. It would be exceedingly difficult to steer an omnibus as long as a tramway car in sinuous courses without involving constant collisions. And, on the other hand, the tramway car, as at present constructed, has the disadvantage of not being able to leave the track when needed. It is helpless when off the rails, and constantly tends to run off when on curves, as may be seen in the process of placing the horses at an angle of 45 deg. with the rails, in trying to keep it on.

Let us begin at the beginning. Tramways are. or should be, supplementary railways, not intended for high speeds, but filling in the links and breaks which impede free transit, and adapted for moderate speeds. Obviously, the road and street surfaces are the best adapted for their application. Upon all roads, the best and cheapest mode of transit is the first consideration. Beginning with our own feet and legs as the means of locomotion, we transferred our heavier loads to the legs of quadrupeds, till we discovered that the power of the quadrupeds could be used most economically in the haulage of wheeled vehicles, and that necessitated firm roads, and the absence of firm roads gave rise to the plank or timber tramway, gradually supplemented by the iron tram of the earlier times. As the iron tram, in its improved condition, permitted heavier loads, it was soon found that steam power was far more economical and capable of far greater development and utility than horse-flesh.

Of all the sources of nuisance in transit through towns and along roads, horses are the worst. It is the dirt of the horses that makes them slip on asphalt as well as on stones, though the joints in the stones limit the amount of slip; and the contrivance of boys to pick up the dirt as it falls, is by no means satisfactory, albeit more cleanly. It is one of the many proofs of the force of habit, that we persist in the use of draught horses when the necessity for them ceases. If there be one advantage more than another in the use of tramways, it is to be found in their applicability to the use of steam as a tractive force. It is imagined that there must be an antagonism between a steam engine and a horse, like a clan feud, to go on forever, the engine being the frightener and the horse the frightened. Now, an engine may run away, as in the case of the road roller in Pall-mall, tampered with by the boys, but it is always amenable to the turn of a handle, if the driver has wit enough to guide it; but the horse may take the bit between his teeth, in a fit of obstinacy beyond control; and even staid, respectable brewers' horses are not superior to occasional frights. Upon the whole, the horse is more mischievous than the steam engine, eight times as costly, and far more dirty. If the legislature would look at the question fairly, giving the engine its due, as they have given horses more than their due, no long time would elapse ere we should behold the extinction of horses in our cities as instruments of drudgery by a similar process to that taking place on farms.

On a well laid street, with a sufficient depth of solid concrete, and a surface of elastic asphalt, there would be no difficulty in applying light traction engines, always subject to the condition of steerage by hand. But to form general road surfaces in this mode would be too costly, unless in cases of a large remunerative traffic. A branch line will not bear the same outlay as a main line. Of the value of the general surface of asphalt there can be no doubt, in its freedom from blows, and noise, and dirt, other than those of the horses; but it can only be adapted for comparatively slow traffic, unless with automatic guidance.

We must, therefore, come to the rail, not necessarily in all cases, for it would be a disadvantage in narrow, crowded streets, unless the vehicles were adapted to leave the rail when needed; but for the larger and general purposes of suburban

transit we possess nothing, in our present state of knowledge, comparable to the wrought-iron rail, as a smooth, even, tough, and unbreakable substance. If we are to attain this condition, we must resort to some mechanical process for obtaining a really permanent way, in the employment of our iron.

We must have such a mode of construction as will permit the laying the rails, when needed, in sharp curves, as sharp as 35 ft. radius, in order to take advantage of street corners and narrow streets as easily as the existing horse omnibuses. We must also so amalgamate the rails with the road surface that they will mutually support each other, and prevent separate sinking or wear. And as rails can only be made in short lengths, the joints must be so constructed as to make them equivalent in strength to the solid portions of the rails. Now let us examine the existing structure.

A pair of timbers, some 21 ft., in length, 6 in. in depth, and 4 in. in width, are laid in trenches in the road, bedded on concrete, which may or may not be solid. To keep these timbers to gauge, a pair of iron castings or saddles are made to clip each timber. Into these castings a dovetailed iron bar is made to drop, keeping these timbers to a specific width. The space between and outside the timbers is packed with paving stones or other material, to form the road surface, and enclose the rails which are flat bars 4 in. wide and 1¼ in. in depth, a groove being rolled in their surface 1 in. in width and ¾ in. in depth, leaving an interior rib 1 in. in width, and an outer rib 2 in. in width, for the wheels to run on. The inner rib is notched on the surface, on the supposition that it will prevent horses from slipping, though the notches are below the general surface. A plate of iron ½ in. thick by 4 in. wide, is laid under the joints of the abutting rails, and iron spikes are driven into the timber, through the rail grooves, to hold them down and keep them in position.

It must evidently be a very difficult thing to lay such rails into sharp curves. The rails may doubtless be bent laterally, but the timber will maintain its right of warping, according to its structure and growth, in any direction, unless used in very short lengths, resisted, doubtless, by the paving horizontally, but not vertically. But in the act of paving, it is quite practicable and common, to burst the cast-iron chairs by too tight ramming, in which case the gauge becomes irregular. The load on each small wheel of the vehicle is close upon 1½ tons when fully loaded, and if the timber springs up and down, a constant battering of the concrete must take place below. If the paving sinks irregularly, the rail projects above it and is exposed to the blows of crossing vehicles; the rails are subject to bend vertically between the timber and the iron-joint plates, and the result is a constant rise and fall of the joints; and the verification of Mr. Haywood's remark, that "the advent of tramways is always accompanied by a condition of bad paving," is indicated by the men constantly employed in the "maintenance of way."

As yet, the tramways are only passing through what may be termed their "baby disorders," but which will yet grow up into chronic disease, only to be remedied by the process of removal at no distant date. They are in a condition of permanent "rickets."

We come now to the vehicles. Were they fixtures, nothing could be better. They are roomy, well seated, capable of good ventilation, convenient in access and exit, and accommodate a large number of passengers. But when moving, the structure is found to be radically vicious. To move at all along the inequalities and curves of the rails with 4 wheel flanges fitting too closely in the iron grooves, enforces the shortening of the wheel base to the utmost. The vehicle is, with its projecting entrances, 24 ft. in length, and the axles are less than 6 ft. apart. If, therefore, efficient springs were used, the result would be great oscillation, far in excess of that experienced in ordinary omnibuses, and so great as to be unbearable. To counteract this, blocks of india-rubber on the axle-boxes are substituted for springs, in which the motion is very small vertically, and *nil* laterally. Oscillation is thus removed, at the cost of incessant, sharp vibration, with a constant grinding noise, and a quick jump of the wheels when they pass over a pebble in the rail groove. Any observant passenger will be familiar with this. Side-yield to obstacles there is none, and the wear of the flanges and grooves, and disturbance of the rails in their sites, is incessant. Where curves are necessary, absolutely the only mode of keeping the

vehicles on the rails is to set the horses at an angle, pressing the wheels inward towards the centre of the curve. To allow the flanges anything like freedom would require a groove upwards of 3 in. in width, and correspondingly wide tires. An omnibus, with its wheels all free, rolls; the tramway vehicle, with its wheels all fast on the axles, and of very small diameter, and its axles always parallel to each other, can scarcely roll at all; it can only be a sledge during a large proportion of the movement, and the effect on the horses tells the tale.

In seeking for improvement on the existing tramway, an obvious advantage would be gained by placing the greatest width of the rail vertical, if the existing form permitted any mode of fastening it, as we should then get the greatest strength in the direction of the load borne on it. The quantity of metal in it is quite sufficient to obtain a good form, wholly independent of timber sleepers and fastenings. It should be a deep rail, with a wide upper table, to suspend it from the surface, and a lower table, to key it into the road, and elastic fishes bolted at the side channels at the joints, forming each line of rails into a continuous bar, equally strong throughout. The best form for the rail top would be an open shallow channel with splayed edges, not needing more than a quarter of an inch in depth in the centre, and dispensing with flanges to the wheels, which would thus run as easily as cab and omnibus wheels run in the iron side gutters of the streets, and would not run out without being purposely drawn out, but could with great advantage turn out when required. Such rails, with the heads 4 in. wide and the stems 6 in. in depth, would form 2 backbones to the road, in the form of iron girders, preserving an even surface, and demonstrating that bad paving is not a necessary accompaniment of a tramway, but only a consequence of imperfect structure. In laying down such rails, the simple plan is to connect each pair of bars to a pair of cross timbers at their upper surface, as a temporary gauge, which timbers suspend the rails at the right level in trenches dug out sufficiently wide and deep, to run in, first, a solid mass of concrete, forming a single block, and on that 1½ in. of asphalt, an elastic and tough bedding, without brittleness or tendency to crumble away, as do hard cements. Thus, the rails being solidly fixed, require no tie-bars, which may be dispensed with. A pair of rails being thus fixed, a second pair are connected to the joints by the fishes, and the temporary timber bars then moved on, to repeat the process. When curves are needed, the rails are bent laterally by the machine, either at the works or on the spot, and there would be no warp or tendency to change of form, and no points or crossings would be needed, for any vehicle would be enabled to pass in or out of the shallow channel.

The only objection to such a rail has arisen from companies, and it is a very valid one from their point of view, viz., that such a rail would offer great facilities for use by the proprietors of omnibuses, cabs, and other vehicles, who have contributed nothing to the cost of the rails. But the facility of making communications from one line to another, and round street corners, and through avenues at present unavailable, would be ample compensation, if made available, greatly facilitating operations, and diminishing outlay.

Supposing such tramways obtained, the next consideration is, the vehicles to run on them; for it is of no use to make curves of 35 ft. radius, and vehicles only adapted to 2 chain radius, or 132 ft. The first condition in the vehicles is, that the axles shall be capable of radiation, *i. e.*, varying from parallelism to each other to such an angle that each axle will point truly to the centre of the curve they may be traversing. This may be done, either by making the axles traverse beneath the body, or by dividing the body with a central joint, not interfering with the passageway through it; but, when this is done, it is essential also that each wheel should revolve independently on its axle, as do the wheels of ordinary omnibuses, or the vehicle will continue to be a sledge on curves. These two points being provided for, the axles may be placed at any distance apart, to guard against oscillation, and thus efficient springs become possible, with wheels of larger and more efficient diameter.

There is yet another and most important point. At present, all wheels and axles are dead weight without elasticity; the springs being above the axles and not below. What is needed is to apply the elastic principle as closely as possible to the rails. Vibration, hurtful to the health

and wasteful to the mechanism, is caused by blows between the wheels and rail, but if efficient springs be interposed between the wheel and tires, the blows will disappear and the vibration also. I have for many years advocated this principle with more or less success, and with mechanical results giving conclusive evidence in its favor. Mr. Thompson, of Edinburgh, in his advocacy of india-rubber tires, has given a valuable impulse to the extension, but the object of Mr. Thompson has been their application to traction engines, as a flattening fulcrum on the road surface, to give better adhesion. Incidentally, such tires have been found to form very efficient springs, to save the machinery from damage. But there is a disadvantage in this external application. A very large mass of rubber, both in width and depth is needed; but as the adhesive pressure is only at the apex of the circle, it is essential to apply a chain and set of iron shoes to tighten it, and this involves cost and trouble. Moreover, it is necessary to use a hard quality of rubber, not so chemically durable. The true position for the rubber is between the wheel and tire, in which case the adhesive pressure extends to half the diameter of the wheel. The value of rubber can hardly be exaggerated. It is practically artificial muscle of universal action, and inside the tire it may be used in the highest condition of elasticity, and at the same time protected against all external damage. A thin tire may be used with it, which will flatten sufficiently to insure contact and adhesion in the case of driving-wheels of engines. For the running wheels of vehicles, it is desirable that the tire should maintain a true circle. We may illustrate it by the action of two blown bladders—the one partially full of air, and the other tightly distended. The former will not roll freely, the latter will. The former represents the condition desirable for the driving-wheel, the latter for the wheel of the vehicle. Such wheels will prevent all blows, both vertically on the tread, and horizontally against the rails and flanges; and when the railway authorities awaken to this fact they will find a very considerable difference in the comfort of their passengers, with an equal reduction of the cost in transit. On a rough road the difference in haulage resistance between an efficient spring vehicle and one without springs, drawn at high horse speed, is as 4 to 1 in favor of the former; and on rails, where the resistance is largely increased by lateral in addition to vertical friction, efficient springs become a matter of paramount importance. Wheels of this kind, applied to a traction engine on the common road, obtained a silver medal from the judges of the Agricultural Exhibition at Wolverhampton.

Amongst other considerations, not the least important is the possibility of speed. Other things being equal, time is equivalent to money; and to obtain great speed from horse traction, with heavy loads, is simply a question of horse killing—cruelty to animals. The average speed of the existing tramways is about 4 miles per hour, and that with serious distress to the horses. What we need is to be able to increase or diminish our speed at pleasure, according to safety. We cannot do this till we resort to the power of steam or elastic gases. Why we have not done this, is because we have not yet produced an engine combining simplicity and efficiency with tortuous transit. The engines of the railways are adapted only for straight lines, and if they run on curves it is at a great cost and waste of power, and they cannot run at all on such curves as are required for the ordinary purposes of streets and roads. Of course the steam power that can be made available must depend upon the load on the driving wheels, and that load must be governed by the capacity of the rails to carry it.

A system of rails such as described, would, without difficulty, carry a load of 2 tons per wheel. Four driving wheels could be used, making a load of 8 tons. Taking the steam power as one-fifth of the insistent load on the driving wheels, that would give a traction force of 3,500 lbs. at the rails. With the resisting friction of the vehicles reduced to the minimum by the appliances before described, the resistance per ton on the level should not exceed 8 lbs., and, theoretically, such an engine should draw a load of 450 tons on the level at 20 miles per hour, or 43 tons up a gradient of 1 in 30 at 10 miles per hour. Of course these speeds could not be used on sharp curves of very small radius, but the speed could then be reduced, and increased on the straight line. With the 2 axles of the 4 driving wheels

4 ft. apart, and a pair of trailing wheels radial, making a total wheel base of 10 ft., the tires of the driving wheels compensating on curves, such an engine would be perfectly adapted to work curves of 35 ft. radius.

One of the purposes which such a line and engine would subserve would be the connection of railways with each other. The open-channel rail would permit ordinary railway trucks to run on it, the wheels bearing on their flanges. They would, it is true, run with considerable friction, on account of the wheels being fixed on the axles, but with the tires made revolving and elastic, this would cease. But they would not work the extremely sharp curves without the axle being made to radiate. The advantage and economy of being enabled to deliver a truck-load of goods or materials from the supplier to the receiver direct, without shifting the load into road vans, would be found so great that all needful appliances would soon follow. The engine described would be far more powerful than needed for street and surburban uses, but it would supply a want on the great public roads of no small amount.

The steam coach of Walter Hancock weighed about 4 tons, but it had 2 large driving wheels, a bad road, and varying and uncertain gradients, and, moreover, insufficient boiler power. These difficulties can now be got over. An engine with a load of less than 3 tons, on 4 driving wheels—a load far less damaging than the existing tram cars—would give a tractive force at the rails of over 1,000 lbs., equal to a load of 125 tons on the level rails, at 10 miles per hour, and could carry a supply of fuel and water for half a day; or could rise an ascent of 1 in 30 with 12 tons load, commanding all the heights round London with, say, 100 passengers, free from all risk of oscillation, and working the sharpest curves.

What, then, are the objections? Only superstition or prejudice. It is supposed that an engine must consist of a dirty-looking boiler, greasy machinery, volumes of smoke, hissing steam, and one or two very dirty men as driver and stoker. The objectors have before their mind's eye a colliery engine, or one of those used as a navvy's assistant. There is about the same resemblance between such an engine and what might be, as between a pleasure carriage and a dust cart. Both go on wheels; but the engine may be built as elegantly as a pleasure carriage. It may have ornamental form super-imposed on its utilitarian structure. It may be painted and varnished, and adorned with utilitarian heraldry of modern times, quite as suggestive as the utility-based heraldry of the olden time—the ploughshares that won battle-fields, or the war-steeds, or cressets, or embattled towers, or iron crowns, or portcullises, or Dragons of Wantley, or Golden Fleeces, or ermined mantles, or barred helmets, or battle-axes, or swords, or scymitars. The fire-king, and the water kelpie, and the Undines, and the Northern gnomes working beneath the seated hills, and the dwarfs of the coal-mines, and Charles Wain, and all the wheels, and valves, and tools of engineering, are at the behest of the modern herald who may wish to curry favor with horses and horse-owners, by showing pleasure-engines in competition with pleasure-carriages, and remove from sight those external indications that offend the aristocratic horse, accustomed to carriage elegancies. Every piece of unpainted metal might be polished as highly as a curricle-bar, and every oil-cap closed by tight valves, and the fuel hidden away, with an ample foot-plate, and every convenience for the driver and stoker, who might thus be quite as clean and smart in externals as the driver or conductor of an omnibus, or the fastidious ruler of a Hansom cab.

"But there is the risk of explosion!" cries another objector. No doubt that risk exists in proportion to the magnitude of the boiler, but it diminishes in proportion to the decrease in size, and to the simplicity of structure. The risk increases as the square of the diameter, supposing the same thickness of metal maintained, and in small boilers the thickness of metal may be beyond all risk. We have not yet culminated to the point of perfection in boiler structure, and the processes we have to take to may be easily indicated. In boiler making, as in other things, we are apt to stick to the existing, and eschew the possible, under the nickname of theory.

But how about the smoke? Nothing very difficult. Smoke is unburned fuel, and simply waste. Coke is a very inefficient agent in producing steam. Coal, which induces lambent flame impinging on the

heating surface, is far more efficient. But coal badly burned may be as inefficient as coke. Every one who pokes a smoky fire knows that the rush of air induces flame, and when locomotive engines smoke we may be quite sure that it is from want of such poking as will give air to the interior mass of heated fuel. The fire should resemble, as nearly as possible, a large lamp, with the fire impinging through the whole fire-box and tubes. In making a fire, or lighting a lamp, the first thing we have to do is to establish a gas-making apparatus. We do so when we light a rushlight, as may be seen by the small blue flame at the bottom. The best fuel, therefore, is that which is most easily convertible into gas, a process which is carried on in every oil or paraffine lamp on our tables, and, if rightly adjusted, without any smoke or smell. The best fuel, therefore, for a street locomotive would be paraffine oil, or some equivalent liquid, which passing gradually into perforated iron tubes in the fire-box, heated by a small fire of coke, would be evaporated into gas, instantly converted into flame by a sufficient supply of air. The question is only of cost, and it may be that effective fuel at a high price per ton is cheaper than low-priced, if tested by the quantity of steam produced. In using solid fuel, the essential question is, how to mix the due quantity of air with the gas as fast as it rises. To accomplish this, interstices must be provided and maintained. With gas this is easy, and the quantity may be adjusted to the demand, by turning a handle, with the greatest facility, without opening the door of the fire-box.

With regard to interstices in solid fuel, there is a manufactured fuel now about to come into the market, formed from coal dust, which, rightly applied, bids fair to supply the want by insuring the presence of air. This coal can be compressed into spheres of a convenient size, and which, when placed in the furnace, only touching each other at points, while the air rushes freely round them, the burning taking place on the surfaces, and the air passages can be maintained till the whole is consumed.

There is another source of annoyance, noise of the intermittent blast; this is now got over in some traction engines by discharging the blast into a chamber, and thence into the open air, in a continuous stream. But the true method would seem to be by splitting it into several currents. The blast of a trumpet is induced by its expanded tube form. Were the opening intersected with wires, the sound would be modulated, and a similar effect might be produced in the steam blast.

In very small engines, the chances of explosion may be reduced to the bounds of a very small possibility, but that possibility may be reduced to an impossibility by varying the medium through which the heat power is used, substituting air for water. In the use of steam, a magazine or accumulator is needed, containing a large supply under pressure. In the use of air, the pressure required is obtained at every stroke of the piston, without any accumulation. Steam is used at a pressure of 100 lbs. to the inch. Hot air does not exceed 15 lbs. to the inch. Therefore, to obtain a given power, a much larger cylinder is required in the case of hot air than is required with steam, and the weight of the machine is increased; but to set against this, the hot air requires no boiler. The blast of air driven through the fire intensifies the combustion, and swells its volume to the required pressure. The sound of the blast in escape is of course subject to the same conditions as the steam engine, and can be dealt with after the same methods. There would be no difficulty in constructing a hot air locomotive, weighing not more than 3 tons, to develop a traction force of 600 lbs. at the rails—a force ample for the purpose of drawing a load of 600 passengers through the streets and suburbs of London.

Such an engine could no doubt be made to do its haulage equally well on asphalt as on rails, with the exception that it would cease to be self-guided, and must be provided with arrangements accordingly.

The outlay for such an engine would probably not exceed that required for the purchase of a stud of horses required for working an omnibus of equivalent load, with the advantage that the engine would work incessantly without falling sick, and that the cost of working it would be scarcely one-eighth that of the horses, and it would not be subject to dying. It would carry with it its fuel for a whole day, eating its carbon while working, instead of knocking off like horses to their oats or maize; and the rises and falls in the price

of fuel would be less than those of the horse food. Moreover, the engine would not destroy the road with 8 pickaxes, like the 8 horse-shoes, and the gases discharged by the blast without smoke would leave no residuum like that marking the track of the horses with a common nuisance. The source of dispute between tramway and omnibus horse owners would cease, inasmuch as horse owners could not live under the competition of steam, or hot air.

The better housing of the working classes, now imperatively urged as a necessary means of national progress, can only be accomplished in its most desirable condition by the aid of cheap transit, and it has been proved that the largest source of profit to transit companies is "third-class," in other words, the great masses of working humanity. The humanizing influence of gardens may be accessible to some of the families of working men as distance vanishes in mechanical facilities. If commercial stimulus induces a company to work in this direction, it will be a great advance on the morals, prosperity, and happiness of our great commercial and manufacturing cities; but till we can get mechanical power substituted for horse-flesh as the means of transit, we shall be as far behind in the results as are omnibuses and stage coaches compared with railways—at a given cost doing only one-eighth of the work.

SEWAGE AS A FERTILIZER OF LAND, AND LAND AS A PURIFIER OF SEWAGE.*

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Though large figures have been put forth, by sundry writers and speakers, of the immense loss this country suffers by casting the sewage of its towns into the rivers, and everybody acknowledges, not only that such waste ought not to continue, but that our rivers should be restored to their original purity, we have not yet brought to practical test the value of sewage to the farmer and the market gardener. Chemists have done their best to rouse public attention to the loss we suffer, and it now remains with the country to adopt those measures which will best conduce to its recovery.

Large as the intrinsic value of the fertilizing matter has been shown to be by the chemist, the value of the water in which it is contained has been excluded from his consideration, though farmers and gardeners alike are prepared, after the experience of the recent years of drought, to put a high value on water for its own sake, irrespective of the fertilizing elements it contains after sewage has been mixed with it, for they know how serviceable is timely moisture to the germination of seed, and for reviving and sustaining plant growth, independently of its special power of conducting to the roots of plants, in the most acceptable way, those fertilizing ingredients which the chemist has valued so highly.

Hitherto, the benefit to be gained by a command of water has been more than counterbalanced by the disadvantages of excess, and the obligation of disposing of the liquid sewage at all times and under all conditions. In referring to water, therefore, I do so only to remark that, large as the theoretical value of the manurial properties of sewage has been declared to be, it may yet bear an increase when the practical mind of the agriculturist is brought to bear on its utilization, and the disadvantages under which a new branch of industry always suffers are overcome.

A HIGH STANDARD OF PURITY OF WATER ESSENTIAL.

But so slow and so naturally sceptical, in respect of new appliances, is the agricultural mind, that we must not wait for the recognition of the cultivator as the only thing necessary for the development of the value of sewage. We must rather trust to the obligation which will before long be imposed on all sewer authorities, so to treat the liquid refuse of towns that the effluent liquid shall conform to a recognized standard of purity; for it will only be by the most stringent enforcement of

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the law in this respect that all the manurial properties of sewage will be rendered available for reproduction.

Taking this view, I think it is much to be regretted that the Conservators of the Thames have, without pledging themselves to any positive decision, recognized a standard of purity in some degree inferior to that suggested by the present Rivers Pollution Commissioners in their first report, and that they have done so in the face of a statement by the Commissioners, that they made the suggestion with the "belief that, as science progresses, improved methods of purifying polluted liquids will be discovered, and that eventually standards of purity considerably higher than those recorded may, if necessary, be enforced." Without presuming to give any opinion upon the details of the standard suggested by the Commissioners, which I know is regarded by some chemists as objectionable, I am content to record the fact that their anticipation has already been in a measure realized. This is not mere assertion; it has been conclusively shown that when natural soil is so prepared, by properly designed deep drainage and deep surface cultivation, that the whole of the sewage distributed upon its surface is absorbed and percolates *evenly* through the soil, the effluent liquid passes into the arterial outfalls from the under-drains purified to a very high degree, and unobjectionable in every respect. Such, in point of fact, appears to be the purification effected by oxidation, resulting from the aëration of drainage and the intermittent use of soil for filtration, that it is not at all a too sanguine view to take, that, with increased experience, we may arrive at a power of restoring water with which sewage has been mixed to its original potable condition.

For the convenience of those interested in the matter, I here give the standard suggested by the Rivers Pollution Commissioners, and will add that which has been circulated by the Thames Conservators. The Commissioners suggest that the following liquids be deemed polluting, and inadmissible into any stream:

(*a.*) Any liquid containing in suspension more than 3 parts by weight of dry mineral matter, or 1 part by weight of dry organic matter in 100,000 parts by weight of the liquid.

(*b.*) Any liquid containing in solution more than 2 parts by weight of organic carbon, or .3 parts by weight of organic nitrogen in 100,000 parts by weight.

(*c.*) Any liquid which shall exhibit by daylight a distinct color when a stratum of it one inch deep is placed in a white porcelain or earthenware vessel.

(*d.*) Any liquid which contains in solution, in 100,000 parts by weight, more than 2 parts by weight of any metal except calcium, magnesium, potassium, and sodium.

(*e.*) Any liquid which, in 100,000 parts by weight, contains, whether in solution or suspension, in chemical combination or otherwise, more than .05 part by weight of metallic arsenic.

(*f.*) Any liquid which, after acidification with sulphuric acid, contains, in 100,000 parts by weight, more than 1 part by weight of free chlorine.

(*g.*) Any liquid which contains, in 100,000 parts by weight, more than 1 part by weight of sulphur, in the condition either of sulphuretted hydrogen or of a soluble sulphuret.

(*h.*) Any liquid possessing an acidity greater than that which is produced by adding 2 parts by weight of real muriatic acid to 1,000 parts by weight of distilled water.

(*i.*) Any liquid possessing an alkalinity greater than that produced by adding one part by weight of dry caustic soda to 1,000 parts by weight of distilled water.

The following standard of purity for defecated water is that recommended by the chemists consulted by the Thames Conservators, and it will be seen that it is, as I have stated, less stringent than that suggested by the Rivers Pollution Commissioners. They say: "1. It should be free from an offensive odor. 2. It should be free from suspended matters, or, in other words, be perfectly clear. 3. It should not be alkaline to turmeric-paper, nor acid to litmus-paper. 4. It should not contain per gallon more than 60 grains of solid matter dried at 260 deg. Fahr. 5. It should not contain more than $\frac{3}{4}$ of a grain of organic and ammoniacal nitrogen per gallon. 6. It should not contain more than 2 grains of organic carbon per gallon. 7. It should contain not less than 1 cubic inch of free oxygen in a gallon." It should be observed, however, that one of the eminent chemists who signed this recommended standard, Dr. Frankland, being

himself a member of the Rivers Pollution Commission, added these words: "The conditions under which fluid which has been contaminated with sewage may be admitted into the Thames, as prescribed in the foregoing report, will, I have every reason to believe, preserve the river from being offensive to the inhabitants upon its banks; but, whilst thus far agreeing with my colleagues, I wish it to be distinctly understood that, in my opinion, such fluid can only be safely admissible into the Thames on condition that the water is not afterwards used for domestic purposes."

The conservators of the river Lee, in the absence of any standard recognized by the Govern ment, have hitherto abstained from issuing one of their own, and the consumers of water in the metropolis are to be congratulated that they have done so; for the publication, limited though it has been, of the lower standard recommended to the Thames Conservators, has already had the effect of encouraging results inferior to those which are to be desired. The Lee Board reserves to itself judgment until the towns discharging into the river have completed their purifying works, for which they have extended the time, at the expiration of which it is to be hoped that some positive action towards the establishment of standards to fit different circumstances will have been taken by the central local government authority. Until such is the case, we shall probably see, both on the Thames and on the Lee, the sewer authorities of towns disregarding, naturally enough, the higher standard of the Rivers Pollution Commissioners, and in spite of the protest of Dr. Frankland, and the general sense of the country, the inhabitants of London may be compelled to drink polluted water, and, as a natural consequence, the contamination of our streams will continue throughout the length and breadth of the land.

This point, however, is not that upon which I desire to dwell. It is of sewage as a fertilizer of land that I must speak, though it is right to repeat emphatically, what must be manifest to every practical mind, that so long as the pollution of rivers is permitted in a modified degree by the recognition of any standard of inferior character, the fertilizing ingredients of sewage will not be wholly recovered from the water with which they are mixed.

SEWAGE AS A FERTILIZER OF LAND.

To show what is the intrinsic value of the fertilizing ingredients of sewage, I will in the shortest manner possible, state the conclusion to which Messrs. Lawes & Gilbert came in 1866, in their very complete and careful paper on the "Composition, Value, and Utilization of Town Sewage," read before the Chemical Society, and which, I believe, expresses pretty accurately views in which the majority of those who are competent to deal with the subject concur. Having adopted the case of Rugby as a fair sample of water-closet towns, the discharged sewage being equal to 36 gallons per diem, or 60 tons per head per annum, including surface and subsoil waters, they stated that, "looking to the average results of 93 analyses," they found "that the sewage contained about 87½ grains per gallon of total solid matter, of which about ⅔ was inorganic and ⅓ organic. About half the total solid matter was in suspension, and half in solution; of the half in suspension about ¼ was inorganic, and ¾ organic, and of the half in solution about ¾ was inorganic, and ¼ organic. Lastly, of the nitrogen, reckoned as ammonia, about ¼ was in suspension, and ¾ in solution. The mean of the 93 analyses showed about 6½ grains of ammonia per gallon, indicating a value of 1⅔d. for the total constituents in 1 ton of sewage." These figures, multiplied by the 60 tons of sewage per head per annum, resulted in showing "that 12½ lbs. of ammonia were contributed annually for each average individual of the mixed population of both sexes and all ages." This quantity of ammonia, at 8d. per lb., gives 8s. 4d., or 100 pence, as the value of sewage per head from water-closet towns. Various other estimates have been made of the sewage of water-closet towns. Dr. Letheby took samples, at noon and at midnight, from a number of sewers in the metropolis, and arrived at the conclusion that 7.24 grains represented the mean quantity of ammonia per gallon. Messrs. Hofmann and Witt, having treated one particular sewer, considered that 8.21 grains represented the quantity of ammonia. These two quantities would, if taken at the same price of ammonia, result in larger figures than those of Messrs. Lawes and Gilbert.

There have been several estimates made of the value of sewage, by modes

of computation differing from that based on the whole sewage of towns as discharged by the sewers, and as they will assist us in considering what proportion of the excrementitious matter of the closet may be kept out of the sewers, with benefit to agriculture and profit to the ratepayers of sewered districts, I will shortly refer to them. Messrs. Hofmann and Witt, and Dr. Thudichum, having ascertained the amount of urine and fæces voided by individual persons, taking an average of both sexes of all ages, valued the urine at 7s. 3d. and the fecal matter at 1s. 2¾d., which together, it will be observed, is very nearly the same amount as that put upon the whole sewage by Messrs. Lawes and Gilbert.

There is an anomaly in these estimates which has to be reconciled, inasmuch as it appears that the excrements of human beings alone, exclusive of the refuse from slaughter-houses, stables, cow-houses, and dog kennels, as well as that discharged from the kitchen, with its refuse of vegetable and animal food, is more valuable than the whole liquid refuse of a town, when the contents of the closet are discharged into the sewers as well as all other refuse. And the anomaly becomes more difficult of reconciliation when we have to consider a statement by the Rivers Pollution Commissioners to the effect that, comparing water-closet towns in which the whole of the sewage issues from the sewers, with "midden" towns, in which a considerable portion of the human excreta is detained and disposed of separately, there is a remarkable similarity of composition between the two.

I will not detain you by any endeavor to reconcile these analyses and statements, but will only remark that, assuming them to be correct, an important consequence follows, viz., that, in an agricultural view, it is desirable to treat the excremental contents of privies separately, for if no appreciable loss of fertilizing matter is found to exist in liquid sewage when separated from that of the privies, it is manifest that a decided national gain is obtained by the maintenance of the two systems, inasmuch as the dry, portable manure obtained from the privy contents will be so much fertilizing matter available for distant lands, in addition to the liquid sewage, which may be utilized by irrigation near at home.

But the realization of the fertilizing value of sewage in the liquid state depends necessarily upon two preceding conditions, the first being the obligation which should be imposed on all towns by the central local government authority, to *perfectly* cleanse their sewage; and the next, the preparation by the sewer authorities of the land designed to receive the sewage, in such a way that the whole may be *fully* utilized. With these two duties performed, and not otherwise, there is a fair prospect of at least a penny a ton being realized for liquid sewage of average strength, half of which (as I have stated on former occasions) should go into the pockets of the ratepayers, in repayment for the necessary works, while the other half will be due to the cultivator as a return for his industry and the employment of his capital.

Excluding from consideration the value of the water, which, I contend, will become a great item in the profitable treatment of sewage, the subject before us may be classified under three heads, viz.—(1.) Where the whole of the sewage is treated by chemical process at the mouth of the sewer. (2.) Where it is transported from the sewer mouth to land for distribution there. And (3.) Where a part of the excrementitious refuse is treated separately from the remainder. The question which addresses itself, therefore, to the authorities of all sewered districts is, which of these methods of treatment will best enable them to effect the twofold object of purifying the sewage and utilizing it to the greatest advantage?—while the question which the agriculturist has to consider is, which method will place at his command at a fair price and in the most productive shape, the fertilizing matter which the sewer authorities must extract, in order to cleanse the sewage perfectly?

I.—*Chemical treatment of the whole of the Sewage at the mouth of the Sewer.*

Leaving out of consideration all treatments which aim only at the purification of the sewage, without turning its fertilizing properties to use, as irrelevant to my subject, I will confine my observations to those chemical processes by which both these objects are said to be obtained. Many processes have been before the public aiming at this end, and several have been patented, and afterwards

brought forward by public companies. The Native Guano Company, better known as the company possessing the patent of the "A B C Sewage Process," now stands very prominently before the public in consequence of its shares being at a high premium, and because arrangements have been made by the authorities of Hastings, Leeds, Bolton, and Southampton, as well as by the Metropolitan Board of Works, to test by comprehensive experiments, the value of the process, although it had been superseded at Leamington by irrigation. The initials "A B C" indicate the principal ingredients of the chemical mixture, viz., alum, blood, and clay, by which it is stated the polluting and fertilizing parts of sewage may be precipitated and made available as a manure. I do not propose to enter into any details of the process itself, but will merely state that the specification of the patent sets forth that 4 lbs. of mixture are required for every 1,000 gallons of sewage treated; and that Mr. Rawson, the general manager of the company, tells me that 100,000 gallons of sewage of average strength—diluted to the extent of 30 gallons a day—will produce from 20 to 25 cwt. of dry manure; from which statement we see that, if the specified proportion of mixture to sewage were adhered to, 400 lbs. of mixture will be required for the production of a ton of salable manure. The company declare that deodorization takes place immediately on the first addition of the A B C mixture, and in proof of the purification effected, give the following analyses:

Comparative Analysis in Grains per Gallon.

	Average of 50 samples Sewage.	Average of 50 samples Effluent Liquid.
Organic matter	17.2	1.4
Mineral matter	37.4	16.9
Total	54.6	18.3

I will now offer such evidence as I can of what the Native Guano Company can do towards the purification of sewage and the extraction of its fertilizing parts, premising that Mr. Rawson has most courteously afforded me every facility for ascertaining the results arrived at by farmers and gardeners who have used the manure sold by the Company.

The Rivers Pollution Commissioners, having made very careful experiments at Leicester and at Leamington, state in their second report (dated 4th July, 1870), that the process removes a very small proportion of the soluble polluting matter from sewage, and that "the manure obtained has a very low market value, and cannot repay the cost of manufacture." Their analysis of the effluent liquid, made of samples taken on the 10th of May, 1870, showed the following result, although the quantity of mixture used was increased very largely beyond the proportion prescribed in the specification (4 lbs. to 1,000 gallons of sewage).

Analysis expressed in parts per 100,000:

Total solid matter in solution	123.05
Organic carbon	4.727
Organic nitrogen	1.892
Ammonia	8.060

These figures are very much in excess of those I have just quoted as given by the Company; though, if the latter were compared with either the standard of purity suggested by the Rivers Pollution Commissioners or that recommended to the Thames Conservators, it will be seen that the condition indicated is not such as to render the effluent liquid admissible into running streams. How Leeds and the other towns mentioned will ultimately conform to a national standard of purity remains to be seen. As to the manure made by the native Guano Company, the Commissioners said that "the so-called A B C manure is little more than the original suspended solid matter of raw sewage plus the insoluble materials added in the A B C mixture, $\frac{1}{20}$ of this being merely clay."

The chemists employed by the Metropolitan Board of Works state, through Dr. Odling (June 24, 1870), when speaking of this process, that, after examination, they found "there was a great deal of putrescible matter in the effluent liquid; and in comparing this mode of precipitation with others, it did not seem that its alleged superiority had any foundation."

Dr. Voelcker, in the "Journal of the Royal Agricultural Society" vol. vi., S. S, Part ii.), having analyzed five different samples of the manure sold as native guano, stated the result to be as follows:

	£	s.	d.	
No. 1 sample was worth	0	18	6	per ton.
2 " "	1	13	6	"
3 " "	0	14	0	"
4 " "	0	18	6	"
5 " "	0	14	6	"

basing his value on a comparison of the manure with phosphate of lime, at £10 a ton, and ammonia at £60 a ton.

Still, in the face of these adverse opinions, expressed by the highest chemical authorities of the country, the Native Guano Company is advertising its dried manure at £3 10s. per ton, and are finding customers at that price. Some farmers and gardeners with whom I have corresponded speak very favorably of it, and declare their intention of buying more, while others say they have not been able to distinguish any advantage from the use of it, and one farmer goes so far as to threaten an action for injury done by its use.

On the whole, the replies I have received do not lead me to the conclusion that the sale of the manure will be very great after public curiosity is satisfied, for it is more than probable that the sales that have taken place have resulted from the desire to give the manure a trial, under a false notion that because Peruvian guano is advertised at £13 5s. a ton, and phospho-guano at £11 10s. a ton, "native guano" must be cheap at £3 10s. a ton. If, however, the sale should continue, the failure of the process to effect purification up to any recognized standard must act as a veto to its adoption, except in those cases where the authorities of towns may be content with clarified in the place of purified sewage.

The Phosphate Sewage Company, founded on a patent taken out by Dr. David Forbes, of which dissolved phosphate of alumina for precipitation is the base, aims at doing all that the A B C process professes to do, with the additional recommendation of being associated with irrigation where circumstances favor the adoption of the two processes, which, seeing that the separation of the coarser solid parts of sewage from the liquid is a desideratum in irrigation, may frequently be the case. The Company state that "if phosphate of alumina alone is used, the sewage is defecated, the solid matter is precipitated, and the water is left still maintaining all its nitrogenous and valuable properties, plus any excess of phosphoric acid which has been added, and, therefore, highly useful for the irrigation of cereals and other crops, and at the same time perfectly inoffensive. This process will be adopted where it is deemed desirable to use the water as a fertilizing agent for irrigation purposes, since it posse ses advantages, both in an agricultural and sanitary point of view, above any system of sewage irrigation hitherto used.

In the case of towns to which sewage irrigation is inapplicable or disadvantageous, and which are desirous of rendering their sewage water sufficiently clear and pure to return into a river or stream, this object can be effected by adding a small quantity of lime to the sewage after treatment by the former process." This Company, in fact, declares itself able not only to purify sewage to a degree to render it admissible into rivers, and to manufacture a manure out of the precipitated matter, but to render the effluent liquid more suitable for irrigation than the sewage itself. These statements are made on the authority of Dr. Voelcker. The analysis of the effluent liquid discharged during certain trials at Tottenham gives the following result in grains per imperial gallon :—

Organic matter—		
In solution	5.74	
In suspension	none.	
Total organic matter		5.74
Mineral matter—		
In solution	57.71	
In suspension	none.	
		57.71
Total solid matter (organic and mineral)		63.45
Organic nitrogen—		
In solution	.47	
In suspension	none.	
Total organic nitrogen		.47
Equal to ammonia	.57	
Saline ammonia	3.32	
Total nitrogen calculated as ammonia.		3.89

Compared with the suggested standard of the Rivers Pollution Commissioners, this analysis does not show the requisite amount of purity.

I have endeavored, from information supplied me by Mr. Lonsdale, the secretary of the Company, to obtain some tangible proofs of the value of the manure manufactured by the Company, but the number of instances are so few in which actual trial has been made on a scale affording any practical test, that I confess myself unable to draw any deductions whatever ; and when stating there can be no doubt that a valuable manure may be

made by mixing with the fertilizing parts of sewage the phosphate of alumina, it must be borne in mind that there exists no proof that the manufacture will be attended with profit. It must also be remembered that the operations of the Company depend upon the supply of phosphate of alumina, which, like all other foreign importations obtained from a distance, must be liable to vicissitudes bearing upon the fortunes of the Company, and on the interests of those towns and districts having dealings with it. Associated with irrigation as a never-failing resource when the phosphate may not be forthcoming or when the manure may not command a sale, such objections would not exist.

With certain seaboard towns, where the effluent sewage need only be clarified to be free from objection, this Company, like the Native Guano Company, may probably do a large amount of work, if it should turn out that a salable manure may be profitably made; though, with the experience we are now having of the power of a small quantity of natural soil to cleanse a large body of sewage by intermittent filtration, and to grow crops at the same time, so that the scavenging powers of vegetation may render their aid in purification (as I shall presently show may be the case), it will probably be found more economical to have recourse to that process which is attended with no nuisance whatever, than to establish manure manufactories with all the attendant risks.

Not having any information to offer with regard to the Peat and Engineering Company, nor of any other chemical or chemico-mechanical processes which deal with the sewage at the sewer mouth, I have nothing further to add about that class of treatment. I will merely repeat that it is daily becoming more generally acknowledged, and acted upon, that "the present resources of chemistry appear to hold out no hope that the foul matters dissolved in sewage will be precipitated and got rid of by the application of chemicals to the offensive liquid," and that therefore we must look to the direct application of sewage to land wherever it can be obtained for the purpose, as the most desirable means of recovering from water those "ingredients held by it in solution and suspension which do not belong to it, and which render it objectionable and unfit for ordinary and domestic purposes."

II. Transport of the whole Sewage in its liquid state from the Sewer Mouth direct to the Land, for distribution on the Surface.

So much has been written and said recently on the practice of sewage irrigation, that I should be disposed to say very little on the subject, had not the special properties of the soil itself for appropriating the fertilizing matter of sewage, and for cleansing the sewage itself, been, to a very great extent, omitted from consideration and had not Boards of Health—the worst farmers in the world—been the principal cultivators up to the present time. Believing that, with a recognition that the soil will perform the functions accredited to vegetation as or more effectually than vegetation itself, and that the two in combination will obtain the best results, both as a means of profit and as a sanitary agency, I regard all calculations that have hitherto been made as to the number of persons contributing sewage per acre, and the rules that have been laid down on that score, as worth very little as a guide for the future, when the principle shall be fully recognized that the surface of land must be rendered so absorbent that no sewage shall pass off into the river courses.

In the application of sewage to land, the local features will, in future, decide the question whether the purification of the sewage and its profitable use should be treated as objects of equal importance, or whether the purification should be the paramount object, and utilization a subsidiary one. If sufficient land for wide irrigation is not to be obtained, or if obtained only at a price that shall place the application of the sewage, by way of irrigation, beyond the possibility of profit, it is manifest that we must call to our aid the cleansing powers of an aerated soil, and regard the land more in the character of a filter than we have hitherto been disposed to do; and by adopting intermittent application, the effect of which has been so admirably explained by the Rivers Pollution Commissioners, realize all the advantages to be gained from it.

The two processes of irrigation and filtration are already viewed so differently from the way in which they were regarded in their first introduction, that it is necessary to state how we stand with regard to them at the present moment. It

will be remembered that, up to very recently, an opinion prevailed with respect to irrigation that, "the object of getting sewage on to the land was, not to let it percolate into the ground, but to keep it on the surface," and that subsoil drainage would not do for sewage farms, because the sewage passed too rapidly to the roots of vegetation, and descended downwards.

Under-drainage as Essential to Irrigation as to Filtration.—Some members of this Society may remember, on the occasion of my reading a paper on "The Water Supply of the Metropolis, in Relation to the Thames and its Tributaries," my friend Mr. Rawlinson, who has ever been the consistent and able advocate of the application of sewage to land, stated in this room, without giving any opinion himself, that some persons practically "acquainted with sewage irrigation would prefer, from their experience, to irrigate clay lands without under-drainage, if Italian rye-grass, which was the most profitable crop, were to be sown;" and the little difference of effect that was to be noticed at Norwood, where the land was clay, and the manager had actually plugged the drains in order to keep the land in a state of supersaturation, when compared with Croydon, where the land is free, and is naturally drained, has often been quoted as a reason why sewage-irrigated land should not be drained. I will not stop to condemn this view, which is repugnant alike to the sanitarian and the agriculturist, as it may be already observed that, with very few exceptions, indeed, operators now disclaim the opinion that under-drainage is unnecessary. So decided has the appreciation of drainage become with the majority of sewage irrigators, that in the eagarness to secure rapid absorption, sewage farms have become filter beds of too rapid action, and by the adoption of inappropriate drains the purifying powers of the soil have been jeopardized. Short as the interval has been since the intermittent downward filtration was first suggested by the Rivers Pollution Commissioners, that process has, like irrigation, undergone a change. The Rivers Pollution Commissioners stated—evidently under the impression that sewage would only be applied to a barren or fallow surface—"That with a properly constituted soil, well and deeply drained, nothing more would be necessary than to level the surface and divide it into 4 equal plots, each of which in succession would then receive the sewage for 6 hours. In this way the sewage of a water-closet town of 10,000 inhabitants could, at a very moderate estimate, be cleansed upon 5 acres of land, if the latter were well drained to a depth of 6 ft." They then go on to state that, nevertheless, there are three formidable objections to the general adoption of the process:—(1) "It is entirely unremunerative." (2) "The whole of the manurial ingredients of the sewage would be absolutely wasted." And (3) "The collection of solid fecal matters upon the surface of the soil, with no vegetation to make use of them, would probably give rise to a formidable nuisance, especially in hot weather." The change to which I have referred has arisen on the proof which I have had the satisfaction myself of affording, that vegetation may be grown upon the surface of filtering areas, even when receiving sewage equal to the discharged refuse of 3,000 persons to each acre, thus adding, in the most apposite manner, to the cleansing powers of the soil the scavengering properties of vegetaiton. When speaking presently of land as a purifier of sewage, I shall give the particulars of the instance referred to, which, though the first and only case in which intermittent filtration has been tried and modified by the growth of crops, cannot fail to prove that the objections anticipated by the Rivers Pollution Commissioners may be avoided.

Technical Description of Irrigation and Filtration.—With the general admission that under-drainage is essential wherever sewage is applied to the surface of land, it must now be generally understood that irrigation means the distribution of sewage over as many acres as it will wet without supersaturation, having in view a maximum growth of vegetation from the amount of sewage applied, and that any departure from this, resulting in excessive application, is a waste of fertilizing matter. I think it may also be taken as proved that filtration through soil should not necessarily mean its application to a fallow or barren surface (as contemplated by the Commissioners), but the concentration of the sewage, intermittently, on as few acres of land as will absorb and cleanse it, without excluding the production of vegetation at the same time.

Irrigation.—Having given the interpretation of irrigation as the application of sewage to as many acres as it will wet without supersaturation, I should point out that, owing to the absence of a proper apportionment of the sewage at command to a certain quantity of land, considerable waste has resulted in most instances of sewage farming. The Italian irrigators reckon that they lose half their water when carrying the other half forward for use; and having the advantage of enormous quantities of water to deal with, and a power of regaining that which was absorbed by the soil, by tapping it at a lower level, they are indifferent to loss; but in England, where we reckon the value of sewage by the ton, and have taken its intrinsic value at 1d. per ton, we cannot be content to follow such an example. We must, in fact, in this country reject any mode of distributing sewage which does not aim at the utmost economy, and which I may here state would not be attained, in my opinion, if the average quantity of sewage applied to each acre per annum exceeded 2,000 tons, which represents the sewage (proper) of 62 persons, with a water supply of 20 gallons a head.

Land may be too Porous.—To judge of the waste resulting from the present mode of applying sewage to the surface of land, we have only to look to the reports of the proceedings at the Lodge Farm, near Barking, published by Mr. Morgan, to whom the public are greatly indebted for the explicit way in which he has given the quantity of sewage applied and of vegetation grown, and we shall see that an average quantity of 4,435 tons of sewage per acre were applied during the year ending the 31st of August, 1870, while the quantity used up to the 31st of August last was 3,808 tons per acre. If we put ½d. a ton—which I have said sewer authorities ought to receive for their sewage—on each of these quantities, we find that the payment in the first year would have been £9 4s. 9d., and in the last £7 18s. 8d. Turning again to Mr. Morgan's report, it will be seen that as much as 21,488 tons of sewage have been applied per acre in one field of Italian rye grass. This at ½d. a ton would amount to £44 15s. 4d. This is the extreme of the year, but taking the whole of the Italian rye grass produced, it will be seen that the average quantity of sewage applied from the date of sowing was 288 tons for every ton of rye grass produced and cut. At ½d. a ton the tenant would have to pay 12s. for this, which is the value of the grass when cut; so that he would suffer a loss of all outgoings in the shape of rent, rates, labor, seed, etc. The waste exhibited by these figures is clearly due to the extreme porosity of the soil, and its unfitness for irrigation on that account.

A Proportion of Clay Desirable.—With the limited time at command I must not enlarge upon the advantages certain soils have over others for irrigation. It may be sufficient to state that, if we desire to make the most of sewage, it is necessary that a proportion of clay should exist in the soil, and that, although very stiff clays, from the difficulty attending their management, should be avoided, it is much more likely that soils may be too free than too stiff; I am now, of course, speaking of the retention of the fertilizing matter of sewage by the soil, and not of the process of filtration as a means of purification. That is quite another matter. That clayey land is more grateful for sewage is very distinctly shown by Mr. Morgan's report, for the same quantity of Italian rye grass was produced from clay lands as from free soils, though Mr. Morgan informs me the former did not absorb more than 4,000 tons per acre, which is a little more than ⅓ of the sewage applied to the Italian rye grass grown on the free soils. I need hardly point out that the rapidity with which land will absorb sewage must depend, not only upon the nature of the soil—its density and porosity—but equally upon the inclination of the surface over which the sewage travels, and the character of under-drainage beneath, and that, therefore, it is the duty of the engineer, when laying out land for absorption, to regulate the inclination of the surface, and the number, position, and size of the under drains *upon which the effect mainly depends*, according to the degree of porosity of the soil, in order that a given quantity of sewage may go as far as possible.

Filtration. — Having dwelt upon the practice of irrigation, I ought now to explain the process of intermittent filtration as it may be carried into practice, but as I shall presently deal with it when considering "land as a purifier of sewage," I will only state that by adopting the pro-

cess as technically described, the liquid refuse of from 1,000 to 3,000 persons—and probably more—may be cleansed by the soil of a single acre of land.

Return from Irrigation.—Up to this time, though sewage-farming has been practised for some years, we have not obtained sufficient data for the guidance of those who desire to follow it as a business. Although local boards and companies have had the farms in their own hands, no balance-sheets, showing the quantity of sewage applied to, and the money realized by the sale of, the various crops grown, have been published. Still, the occasional results that have been obtained afford us positive evidence of what will be done under the management of men practised in the cultivation of land.

The following table exhibits certain results obtained at various places at different dates :—

Description of Crop.	Years of Production.	Place.	Value of Crop Per Acre. £	s.	d.
Italian rye grass	1868	Norwood	22	0	0
	1869	Lodge Farm, Barking	25	0	0
	"	Norwood	25	0	0
	"	Edinburgh	32	0	0
	1870	Lodge Farm, Barking	37	0	0
	1871	" "	22	0	0
	"	Warwick	12	14	0
	"	Banbury	13	16	10
Mangolds	1870	Lodge Farm, Barking	32	0	0
	1871	" "	44	0	0
	"	Warwick	26	5	0
	"	Rugby	21	9	0
Swedes	1871	Warwick	26	5	0
	"	Rugby	18	15	0
	"	Banbury	14	6	8
Carrots	1869	Lodge Farm, Barking	38	0	0
	1870	" "	45	0	0
	1871	Rugby	45	0	0
	"	Warwick	35	0	0
Parsnips	1868	Lodge Farm, Barking	35	0	0
	1870	" "	35	0	0
	1871	" "	52	0	0
	"	Warwick	35	0	0
Cabbages	1868	Lodge Farm, Barking	35	0	0
	1870	" "	15	0	0
	1871	" "	24	0	0
	"	Banbury	21	11	6
	"	Warwick	35	0	0
	"	Rugby	15	0	0
	"	Merthyr	20	0	0
Potatoes	1869	Lodge Farm, Barking	33	0	0
	1870	" "	25	0	0
	1871	" "	18	0	0
Onions	1869	" "	38	0	0
	1870	" "	62	0	0
	1871	" "	104	0	0
	"	Warwick	35	0	0

From these instances sufficient proof is afforded that, with one crop per annum of a kind that will yield largely to the application of sewage, and command a certain and ready sale in the neighborhood, a sufficient return may be gained to pay a full rent for the land and a halfpenny a ton for the sewage, besides affording a good profit after paying all out-goings in the shape of rates, taxes, hand and horse labor, repairs and restoration of implements, seeds, interest on capital, etc. It is true that crops as large and even larger than those grown with sewage have been produced by good farming without sewage, and there would be nothing to say specially in favor of irrigation, were it not that the *united* advantages of manure and water insure crops year after year under every vicissitude of season, and allow of two crops being taken from the same land occasionally. From the experience gained in the cultivation of Italian rye-grass, it is found that it may readily be

grown in excess of the demand for it in a green state, and that, as this description of grass is most difficult to convert into hay, it is desirable to limit its growth to a narrower space. It absorbs and appropriates, however, a larger proportion of sewage than any other description of crop, and it is only because it thus helps to swallow up sewage that it is continued to be grown by those who seek rather to get rid of the sewage than to make the most of it. That specialty loses its force directly a fair value is put on the sewage, or when sewage is applied to land which is itself capable of absorbing and cleansing it, as in such case the manurial matter is stored in the soil for use by following crops.

Return from Intermittent Filtration.—The acreage return to the cultivator from the growth of crops on land used for intermittent filtration will depend upon the extent to which the intermittent principle is extended. If several series of filtering beds are adopted, as I have advised in the case of several towns, among which I may mention Birmingham, where the Sewage Inquiry Committee have declared their intention to adopt it, the return will be found to be quite as great if not greater than that to be obtained from irrigation; for with the land rendered actively absorbent by drainage and deep cultivation, and laid up in bouts or ridges, crops may be grown while the sewage is being applied, without suffering from excess of wetness. By extending the filtering process from one series, as suggested by the Rivers Pollution Commissioners, to several series of areas, so as to give two or three years' rest from filtration, such lands become available for the growth of the greatest amount of vegetation that can be produced from the land; for with the sewage at command, any amount of watering that the crops require can be obtained by diverting the sewage for a time from the filtering areas in use. At Merthyr, the money realized by the sale of crops, comprising various roots and cabbages, grown between the 14th June and 31st August last, amounted, on an average of a day's sale by auction, to £17 15s. per acre, while the crops which were sold afterwards realized upwards of £20 an acre. These figures will bear comparison with the returns from irrigation proper; and I may here state that although the works have been very costly, owing in a great measure to their being the first of the kind carried into execution, and in being themselves the result of Chancery proceedings, the Chairman of the Board (Mr. William Jones, of Cyfarthfa), says in a letter to me that much as the land and works have cost, "the filtering areas may yet pay;" adding that "had we obtained the land at a fair agricultural value, and the works been executed at the cost they would now be executed for, with acquired experience, I have no hesitation in saying that they would be a source of great profit to the ratepayers of this district." These figures and the chairman's opinion are encouraging, and show a fair prospect of profit, if the authorities who have charge of such works abstain from growing the more refined kinds of gardeners' crops, which involve expensive hand-labor, and which are dependent on very fickle markets for sale.

Many considerations lead to the conviction that it will seldom be within the power of the sewer authorities of towns to adopt the widest use of sewage, which would result in the provision of one acre for rather more than 40 persons, if we adopt the rate I have before stated, of 62 persons to one acre, with an allowance of 50 per cent. additional land for increasing population. With constantly arising opposition based on a fear of a nuisance (which under proper management will not arise), the difficulty of obtaining land, and the high price to be paid for it, will always stand in the way of wide irrigation. To compensate for the limitation these obstacles will impose, it must not be forgotten that the produce of sewage farms loses much of its value directly it overreaches the home market, and with a large area used for irrigation in the neighborhood of a town this may be easily done. Already we hear of the produce of the Warwick Sewage Farm being sent to Birmingham, and that of Romford to Liverpool, and various instances of a like kind might be mentioned. One great advantage in the adoption of intermittent filtration, in the shape of concentrated irrigation, is that a greater variety of crops may be grown, and the over-stocking of the market with vegetables avoided, inasmuch as by giving each series of filtering areas a rest of a year or two, the growth of cereals and other crops, which are not

successfully grown by ordinary irrigation, would take their part in rotation, and thus dispose of those manurial elements which might otherwise be left in the soil.

It would be too sanguine a view to suppose that the ratepayers of a district adopting the filtration process in its narrowest form would receive as much for their sewage as when irrigation is adopted under advantageous circumstances, in its widest form; but it is more than likely that, in a majority of cases, a better return may be gained from a medium course of action than from any other, though it is our duty, in a national point of view, to aim at making the most we can of the valuable matter with which we have to deal.

III.—*Separation of the Excretal Closet-matter from the Liquid Refuse of the Sewer, and dealing with each separately.*

As already stated, the treatment of the excremental contents of the closet separately from the liquid sewage of the sewers, is an object in which agriculturists must take a very great interest, though I have never yet met with any estimate of their value. Reverting, however, to the figures given as the value of the voidings of human beings, it would not be too much to take a fifth of the intrinsic value quoted (8s. 5¾d.), or 1s. 8½d. per head of the population, as the value of that which is retained in the closet, and which is capable of separate treatment, and is easy of removal to lands which cannot partake of the liquid sewage.

As the subject of this paper is limited to the fertilizing powers of sewage and the purifying powers of soil, it forms no part of my purpose to discuss the question whether town authorities act wisely in maintaining such a species of scavenging as is involved in the removal of the excretal refuse apart from the liquid sewage. I am, however, prepared to state that, having examined several dry processes now in use, there are some that may be adopted without objection, though it cannot be expected that the occupiers of superior houses, who have once enjoyed the comfort of well-supplied and well-constructed water-closets, should abandon the advantage and resort to dry closets of any description. At Rochdale, Alderman Taylor has patented a plan which is now in use there. Beneath each seat a receptacle containing a small quantity of a disinfecting fluid is placed, in which the fæces and urine are collected. The receptacles are removed in a covered cart weekly, or more frequently if required, to a manufactory on the outskirts of the town. There they are mixed with fine ash reduced from the cinders and dry refuse collected from the houses. The larger cinders, when separated from the ash, are sold. The average price realized for the manure mixture has been 17s. per ton, affording a profit after deducting all expenses, of 2s. 5d. per ton. At the price mentioned, the manure is readily sold, and I can well believe is of great value to the farmer, particularly for certain descriptions of grass lands.

In large manufacturing towns, where water is much required in the trade that supports the population, and where it is desirable to economize as much as possible its use, and therefore to avoid water-closets, Alderman Taylor's process has much to recommend it, and from personal observation I am able to declare that it is free from the many objections that attend badly-constructed and badly-managed water-closets. In fact, I examined many closets attached to cottages in Rochdale which were much more creditable than many of the water-closets attached to large establishments in the metropolis.

But whatever may be done with the excretal matter by dry appliances, it will not be possible to avoid the proper disposal of the sewage of the sewers, and that will still have to be done by one of the classes of treatment already explained.

In small towns and villages it is still to be hoped that the dry-earth system, invented by the Rev. Henry Moule, may be more generally adopted. The experience gained, however, shows that the frequency with which the closets get out of order, and the difficulty of supplying and removing the earth, is such that, unless a system of management is organized and enforced, they cannot gain much ground. Where there exists a proper officer, with assistants, if necessary, to supply the earth and remove the soil, and to keep the closets in working order, it is impossible that anything can be more suitable for isolated establishments and country villages; and when it is remembered that

the difficulties of providing a public supply of water to villages are such as to be insurmountable in many cases, and that the leaky condition of the privy and cesspit maintains the soil in close villages in an excrement-sodden condition, resulting in the pollution of tank or well water, it does appear almost incomprehensible that the governing powers of this country should permit the continuance of the present state of things.

LAND AS A PURIFIER OF SEWAGE.

Having spoken of the general purification of sewage by land, when treating of irrigation and filtration, it is only necessary to add a brief description of the process of intermittent filtration, as it has been carried out under my directions at Merthyr-Tydvil. There 20 acres of land have been laid out for the purification of the sewage of the district, of which the dry weather flow at the time when the works were commenced amounted to 870,430 gallons per diem, the least flow during the day being 500 gallons; and the greatest 663 gallons a minute. The population contributing this sewage exceeds 50,000, but at present less than half the houses are connected with the sewers, so that the sewage may be taken as equivalent to the discharge of about 30,000 people. The number of water-closets being few, the sewage may be considered to be weak. Upon occasions of rainfall (which is above the average), the flow of the sewers is much increased, the storm waters frequently raising the discharge at least 50 per cent. above the ordinary dry weather flow, and this excess finds its way to the filtering areas. The 20 acres of land were divided into 4 equal parts, and before forming the surface to receive the sewage the whole was drained from 5½ to 7½ ft. deep, and deeply cultivated. By this means 2 cubic yards of soil for every square yard of surface became serviceable as filtering material, there being but very few rods of ground in which the full depth of 6 ft. was not secured. The quantity of filtering material was fixed upon so that the maximum quantity of sewage which would at any time have to pass through each cubic yard of soil would not exceed 7½ gallons per diem, while the mean quantity of dry weather sewage would pass through at the rate of 5 gallons per cubic yard. The under-drainage was so designed that no sewage could travel over the surface directly above the drain, which is the case in instances of irrigation of free soils in which the results have not been so favorable.

Here the result has been the most complete purification of the sewage up to this time, and the realization of the fact that the effluent water from the under-drains was as pure when the whole of the sewage was passing through half the filtering areas, viz., 10 acres, as when it passed through 15 and 20 acres, showing clearly that a less number of acres than 20 acres would suffice for the purification of the quantity of sewage dealt with, and that therefore if the sewage had been double the strength or double the quantity, as it may ultimately be when the whole of the sewage of the 50,000 persons is discharged by the sewers, there will be a certainty of complete purification of the whole if the Board manage the works efficiently now they are completed.

During the period when the existing sewage, increased at times by the rainfall, was discharged upon the 10 acres (half the areas), they were receiving as much as 144,000 gallons per acre, which is equal to a depth of nearly 6¼ in., and never less than 72,000 per acre (equal to a depth of 3¼ in.).

Instead of following the mode of distribution usually adopted in sewage irrigation when the fluid is either run over a regular surface, or along the ridge to flow over the slopes on either side, the surface of the Merthyr filtering areas was laid out in the ridge and furrow form, as before explained, the object being to allow of the use of the horse and hand hoe, and while growing crops on the ridge to allow the sewage to flow in the furrows, and rise up to the ridge sides with a certainty of being absorbed, and of feeding vegetation at the same time. This treatment has been so successful that, in spite of the deposit of the finer particles of floating matter in the furrow, the whole of the sewage has disappeared within 4 or 5 hours after application, and the land has acted as a purifier up to this time in such a way that the effluent water from the under-drains is pronounced by Dr. Benjamin Paul to be cleaner than the Thames water above the intakes of the metropolis water companies. In order that its condition may be compared with the standard suggested by the

Rivers Pollution Commissioners, I here give the analyses of the discharge from the 10 and 15 acres, when the whole of the sewage was run through those quantities of soil :—

Results of Analyses in Parts per 100,000.

Solid contents—	Effluent water from 10 acres.	Effluent water from 15 acres.
Total	39.00	55.00
Fixed	34.00	34.00
Volatile	5.00	21.00
Ammonia	.082	.086
Organic matter	.018	.011

Though it is a subject of personal satisfaction to me to have been the first to test, by designed operations, the process of intermittent downward filtration, suggested by the Rivers Pollution Commissioners, and to prove by direct evidence that the objections they anticipated can be avoided, the result might have been expected from the circumstances that in every case where sewage has been utilized on land, and allowed to pass through the soil as well as over it, the effluent water has been perfectly satisfactory. This will be seen by the following analyses of effluent water discharged from lands which have absorbed the sewage without any overflow from the surface, and without being laid out for intermittent action, except in the case of Merthyr-Tydvil, which I have described.

Parts per 100,000 *feet.*

Date.	Place.	Total Solid matter in solution	Organic carbon.	Organic nitrogen.	Ammonia.	Chemical Authority.
1868:						
September 10	Bedford	76.8	.575	.163	.023	Rivers Pollution Commissioners.
" 23	Carlisle	28.8	.591	.204	.025	" "
" 24	Penrith	21.9	.320	.108	.001	" "
1870:						
July 9	Convalescent Hospital, Walton	10 87	..	.002	.002	Dr. Odling.
" 24	Breton's Farm, Romford	70.60	..	.037	.003	Dr. Russell.
1871:						
September 4	Merthyr-Tydvil	39.00	..	.018	.082	Dr. Benj. Paul.
" 4	Lodge Farm, Barking	91.3	.676	.198	.005	Dr. Frankland.
" 12	Tonbridge Wells	34 44	..	.060	.03	Dr. Voelcker.

If the proportions of polluting matter indicated in these analyses are compared with those contained in the effluent liquid discharged from the chemical processes to which reference has been made, or even with those of the effluents from the surface of lands over which sewage has been passed, the superiority of the combined effect of filtration associated with irrigation must be acknowledged. And on a study of all the facts such comparisons will expose, it will be manifest to every unprejudiced mind that, not only is it possible for town authorities to conform to a high standard of purity, but that, with a comparatively small quantity of land at command, it is a simple and inexpensive thing to do.

If this be true, ought there to be any hesitation in adopting a standard so high as to remove all doubt on the subject, with compulsory powers to enforce it?

We have had mournful proof that polluted water will find its way into the palace of the powerful as well as into the cottage of the poor; and our Society has special reasons, in the very serious illness of our Royal President, the Prince of Wales, which has aroused the anxiety of the whole nation, and which is said to be traceable to impure water or sewer gases, for exerting all the power it possesses in preventing the public interests being sacrificed to the influence of water companies, and the false notions of economy which prevail with local Boards of Health.

HYDRAULICS AS AN EXACT SCIENCE.

By H. HEINEMAN.

Translated from "Zeitschrift des Vereines Deutscher Ingenieure."

It is not our purpose to give a complete history of the origin and progress of the science of hydraulics, but to examine its present condition. The essential results of the experiments and investigations of engineering authorities are recorded in our modern text-books. Of these the works of Weisbach and Rühlmann have the widest circulation.

In referring to these works in the course of this criticism, though we recognize the valuable contributions of their authors to hydraulic science, we shall expose and attack their errors. We fear that we have before us an ungrateful task; but in undertaking the demolition of a decayed, falling structure we are clearly determined what to set up in its place.

We begin with the flow of water from vessels. It is not to be denied that this is the section of hydraulics in which a theory has been deduced from experiment that leaves the least defect to be supplied; and for this great credit is due to Weisbach. Still, in almost all cases in which this theory attempts to establish itself upon a rational foundation of observed elementary phenomena, it comes into conflict with both the experience of the practical man and the simplest and most certain of the laws of geomechanics. Whenever it has fortunately avoided these rocks it usually follows that it reasons in a circle, and achieves only an apparent demonstration.

All the elementary works on hydraulics introduce the science with the attempt of John and Daniel Bernouilli, to deduce a rational formula for the velocity of discharge from an orifice in the bottom of an indefinitely large vessel; which gives a result contradictory to the elementary conceptions of force, mass, acceleration and mechanical effect. Upon this the whole later superstructure rests in a greater or less degree, so that the necessary result is an inextricable tangle of obscurities and inconsequences. It is impossible to do more than make a rough conjecture as to the forces, accelerating and retarding, which determine the motion of water. We hardly refrain from expression of our wonder when we see to what resorts hydraulicians have been driven in their attempts to establish in diverse ways their untenable theories. Rühlmann begins his deduction on a correct geometric basis, if one overlooks his hypothesis, entirely contrary to fact, that the different layers of water in a vessel can descend with different velocities without losing their primitive relative connection, or partially mingling, so as to lose their original identity. He thus obtains for each element, for a fall h, a velocity $v = \sqrt{2gh}$, but leaves undetermined how many such elements are discharged in a unit of time.

Weisbach begins his proof with an assumption nearer the truth: that the prism ah, which at first rests over the opening a, is set in motion by the action of gravity. This prism is hindered from free falling only by its cohesion with the surrounding water. This cohesion also acts as a resistance to discharge. Neglecting this, and regarding the descent as free, so that it is continually maintained at the height h by the supply, we find that a column ah falls from surface to orifice continuously, and the centre of gravity must descend a space $\frac{h}{2}$ below the bottom of the vessel in order that it may describe a space h. That which is true for the column ah must hold for n successive columns, and therefore for the quantity Q discharged in a second. In order that this may absorb the mechanical effect $Q\gamma h$, either the mean depth must increase the space $\frac{h}{2}$ by an additional $\frac{h}{2}$, or a second depth or head h must act in addition to the head h of the water in the vessel. Weisbach's investigation unconsciously assumes this when it determines that the mechanical effect of the quantity of water discharged from an orifice of area a in the thin bottom of a vessel is $Qh\gamma = avh\gamma$, instead of $\frac{1}{2}$ this value. Hence Weisbach's method conducts us, not to the velocity of dis-

charge from an indefinitely large vessel, in which the surface of the water is at rest and in which the initial motion must be continuous; but to the velocity of discharge from a vessel into which water enters with a velocity equal to that of the discharge; as, for example, from an orifice under the head $Q\ a\ h\ \gamma$. In this case we have the correct formula.

$$v = \sqrt{g\,(h+h)} = \sqrt{2\,g\,h}.$$

It corresponds also to the free fall of a water-prism in a vessel of constant cross-section whose orifice-area is equal to the section—*i. e.*, a tube. The same result should be obtained from the formula of Bernouilli (by making $A = a$)

$$v = \sqrt{\frac{2\,g\,h}{1-\frac{a^2}{A^2}}}$$

in which A is the cross-section of the vessel, and a the orifice-area. The pure mathematician is alarmed when he finds that this condition makes v infinite, although his data have been determinate and finite; for the length of the tube h and the area $A = a$ may be taken very small, and the Atlantic Ocean may be assumed as the source of supply at the upper orifice. The solution of the riddle is found upon a critical examination of Bernouilli's formula. Besides the fundamental error, we find a lack of precise discrimination as to the question whether the supply-water owes its velocity to the height h, or to some other head external to the vessel. Correcting the error, we have

$$v = \frac{\sqrt{g\,h}}{\sqrt{1-\frac{1}{2}\cdot\frac{a^2}{A^2}}}$$

a formula very similar to that of Bernouilli, and, within certain limits, giving results nearly, if not exactly, the same, but differing from it when $a = A$; for in this case it gives $v = \sqrt{2\,g\,h}$, which correctly expresses the fact, that under this hypothesis the water must fall without hindrance through the tube, there being no molecular resistances; or that it enters the tube with an initial velocity equal to that of discharge.

When we examine the superstructure upon this insecure foundation, we find that it resembles a stone-heap of disconnected pieces, brought together by experiment, with mortar joints outside, but without organic bond. The primitive law determining all phenomena of discharge is wanting. For it, has been substituted a great number of empirical coëfficients, obtained from separate and combined observations. The selection and combination of these with reference to practical needs, so as to compensate, as far as possible, for the want of a rational law, must be credited to Weisbach. But there is, as in every empirical theory, a limit to the range of the coëfficients, which must be approached with caution.

With the exception of the principles of the Bernouillis, we find no independent attempt to deduce rational laws for the theory of discharge, and the relations of hydromechanics to geomechanics. We find, again, that such laws are assumed in the theory of the power and resistance of fluids. Let us see if this assumption is well made.

In Weisbach, §420, after a long investigation, we are led to this principle: "The reaction of a horizontal stream is equal to the weight of a column of water whose base is the cross-section, and whose altitude is twice the height due to the velocity." We hope at some future time to be able to dispense with a special proof of this principle, for the reaction upon the posterior surface obviously cannot be anything different from that which the water exerts at the orifice of discharge in the anterior wall. But the force must be exactly equal to that which the velocity of discharge v, through the orifice a, can produce; that is, to the weight of a column of water having a base a and a height $\frac{v^2}{g}$, or a base $2\,a$ and a height $\frac{v^2}{2\,g}$, which signifies double the height due to the velocity. Every other attempt at proof must either overlook this simple geomechanic principle, or, so long as the fundamental error is not corrected, must be merely an attempt to compensate for one error by introducing another, so as to obtain a result which agrees with facts. Let us seek for the error, and its cover in Weisbach's method. For this, the lateral motion serves, which the vessel must make during the efflux with the velocity v, without influence upon the result, because v appears in the proof only to disappear as soon as it has done its duty. But this duty it has done but imperfectly; for, after it has been certainly shown that C_2

stands for the absolute velocity of the water on entering the vessel, we again come to this conclusion: "But the mechanical energy of the water before discharge, and therefore on entering the vessel, is

$$L_1 = \left(\frac{C_2^2}{2g} + h\right) Q\gamma."$$

Hence the mechanical energy, $h\,Q\,\gamma$, which is due to efflux under a head h, is already assigned to the water when it enters the vessel. In the progress of the investigation, it happens that in consequence of the error the estimated difference of the energy before discharge *minus* the energy after discharge—in other words, the amount of reaction—has a positive sign, while anyone would expect it to be negative. Correcting this error, by rejecting the erroneous h, and making the arbitrary lateral velocity of the vessel equal to zero, we have more simply and quickly $L_1 - L_2 = -h\,Q\,\gamma$, which is the work of reaction. It is only necessary to divide this by the constant velocity C, remembering that $\frac{Q}{c} = a$ the orifice area, to obtain the reactive pressure $Z = -h\,a\,\gamma$.

But $h = \frac{c^2}{2g}$ signifies the simple height due to velocity. But the problem was to obtain $-2h\,a\,\gamma$, which got the negative sign by the doubling referred to.

Again, the next principle is this:

"The normal impulse of water against a plane surface is equal to the weight of a column of water having for base the section of the stream, and for height twice the height due to velocity

$$= 2h = \frac{2c^2}{2g} = \frac{c^2}{g}."$$

We have as little need as before for proof, as soon as it is shown that $\frac{c^2}{g}$ is not twice the height due to the velocity, but the exact height itself. The force which acts against the vessel clearly must be the same as that exerted against the stream, and this is $\frac{c^2}{g}\,a\,\gamma$; a being the sectional area, and γ the unit weight. Let us again seek for the covering error.

Weisbach (§§ 498, 499) supposes a surface of revolution, with an inclination α to the axis of the stream. He supposes the stream to issue with a velocity c, while the surface yields with a velocity v, in the same direction; and he proceeds with the assumption that the stream moves along the surface with a velocity equal to that of the first impact. A condition is again assumed without proof, which in our judgment requires demonstration quite as much as the principle sought to be established. Then follows a correct and logical deduction, which, however, has not the remotest relation to the actual phenomena of impact of water. An arbitrary quantity Q, of weight $Q\,\gamma$, meets the surface with a certain velocity in a certain direction. The result is correct, viz., that the force of impact is the quotient of the velocity into the work.

$$P = (1 - \cos.\ \alpha)\,\frac{c^2}{g}\,Q\,\gamma.$$

This purely geomechanic equation holds for any value of c or of Q, and is independent of the duration of impact. But Q is a function of the time of discharge, and without determination of this, is an indeterminate magnitude. In 10 secs. there is impact of 100 times as much as in $\frac{1}{10}$ of a sec. Hence we can as correctly put Q equal $\frac{n\,c}{n}$ as $n\,a\,c$, and though velocity and orifice remain constant, can vary it from zero to infinity. It is therefore purely accidental that P takes a value agreeing with its actual value, when we put $Q = a\,c$, the amount of discharge in a second.

This indefiniteness of the conceptions introduced into the investigation is shown when we put $v = 0$; that is, assume that the surface is at rest; and $\cos\ \alpha = 0$, that is, suppose the direction of impact to be normal. We then find the work expended on the surface $P\,v = 0$. Dividing both members by $v = 0$, we have $P = \frac{0}{0}$. It follows that impact against a surface at rest is an indeterminate magnitude, while it follows from the equation $P\,v = 0$ (though often hitherto doubted), that a stream of water impinging on a surface at rest, suffers no loss of living force on account of the impact. This result is by no means proven, and was regarded as not proven, in the assumption that the stream leaves the surface with a velocity equal to what it had at first impact.

We find an attempt at rational proof of the same principle in § 163 of Ruhlmann's book. In this the actual phenomena are considered. The stream of water, according to the author, forms a cone equilibrated

on all sides with base on the plane and vertex in the stream. If the plane is large enough, the side of the cone forms a quadrant of a circle to which stream-axis and plane are tangent. Unfortunately this proof also begins with a hypothesis not proven, that the stream spreads over the surface with a velocity equal to its initial value. The resistance (which the plane must exert in order to cause this deviation from the original direction of the stream) is now correctly determined. In geomechanics the theory of centrifugal force gives the fundamental formula

$$P = \frac{m v^2}{r}$$

From this is correctly found, for constant pressure on the surface,

$$P = \frac{v^2}{g}, a \gamma \frac{K L}{2 r}$$

K L and 2 r are magnitudes determined neither by probable hypothesis nor by experiment; namely, the diameter of the base of the cone, and twice the radius of curvature of deviating stream. We have only to assume

$$\frac{K L}{2 r} = 1$$

to obtain the desired result

$$P = \frac{v^2}{g} . a \gamma.$$

By actual experiment we meet the surprising fact that, independent of the velocity, the diameter of the stream is to that of the base of the cone as $1 : \sqrt{2}$; while K L : 2 r at the outer edge of the stream as 3, 5 : 1, and at inner edge as 2 : 1, so that $\frac{K L}{2 r}$ varies from 3.5 to 2.

In view of this, of what value is this laborious investigation? Taking in the process of proof at a glance, we find that it is an able but discursive treatment of this simple question: "What power must act continuously in order that in every second of time a quantity of water, Q, moving with a velocity, v, shall be made to deviate from its original direction by the angle a?" Geomechanics solves this problem without assumption, and by synthetic combination of its most elementary and incontrovertible principles.

In the theory of the impact of water no attempts at demonstration have been made to which the hydraulic engineers of our time assign more than a conjectural value. The like is true of the theory of the motion of water in tubes and in streams; yet it may be of interest to take a brief survey of the progress which efforts in this direction have achieved, and of the standpoint which they have so far reached.

If one attempts to derive the phenomena of motion of fluids from the well-established laws of geomechanics, and in so doing commits an error, and then attempts to reconcile the discrepancies by hypotheses about the magnitude and nature of resistances, the investigation of these resistances must be very difficult because of the false steps taken in the course of reasoning. Although he may admit that resistances which oppose the free fall of water must depend exclusively upon cohesion and adhesion, still he cannot rise to the conception that in this matter we have to do with molecular forces, which are entirely independent of the circumstances of motion of the masses, being variable only as functions of the temperature, and of conditions of aggregation, but invariable between two molecules of the same chemical and physical constitution. It is admitted that two entirely different forces oppose motion, one of which increases as the first power, the other, as the second, or some other power, of the velocity of the water. This is correct, for only under this condition can we maintain the hypothesis of a uniform motion of water, without contradicting other phenomena of the visible world.

Uniform motion in an absolute sense is merely an ideal conception of writers on mechanics, who make use of it to fix the notion of the differential of velocity or space in case of variable motion. Nature recognizes only uniformly accelerated or retarded motion, utterly abhorring that which is constant. Whenever a body is left to itself and not guided along artificial channels, we can discern no case in which the path described is either straight or circular. Gravity, by means of its continual resistance, prevents persistence in uniform motion along natural paths.

If the accelerating force is equal to the retarding resistance, no motion ensues, or that only is maintained without change, which the mass possessed before the action of the force and resistance began. Any excess of one over the other can mani-

festly cause only a continually varying motion.

If we suppose that we thus find an apparent contradiction between geomechanic and hydraulic laws—as, for example, in case of motion of water in tubes—we have not attained a clear conception that the amount of motion is generally a function of two factors, the mass and the velocity, and that increase or decrease of motion may be the consequence of the increase or diminution of either or both of these. Geomechanics has made us accustomed to a certain one-sidedness of view, since it generally represents the mass as invariable, and the velocity as changing. Hence we need an extension of our usual range of views, in order to solve the problem before us; and in the lack of this we must seek for the reason that all previous attempts in this direction have been abortive. The simpler and more closely connected the forces of nature in the primitive constitution of a body, the more manifold and complete are the phenomena of production of energy. We find modern science continually attempting investigation in the primitive constitution.

So far, mechanics has developed only two fundamental principles to apply to all known phenomena of nature. One represents the measure of the magnitude of a constant force, P, by the product m, p, of the mass into the increment of velocity (acceleration) in a unit of time. The other represents the work done during a time, t, by the product $P\,s$, of the force and the space described. From both these principles it follows that the magnitude of the mechanical work done or absorbed in a given time does not give the least clue to the determination of the magnitude of the force acting. For the same force P we may put either $n \cdot \frac{m\,p}{n}$ or $\frac{m}{n}\,p\,n$.

In the first case the work done in the time t is $P\,s = \frac{m\,p^2\,t^2}{2\,n}$; in the second, $P\,s = \frac{n\,m\,p^2\,t}{2}$. Putting $n = \infty$, the work in one case is infinitely small, in the other, infinitely large. In none of our geomechanic operations have we had opportunity to make this relation clear and precise to our understanding, because these always deal with constant mass and varying velocity, while in all hydraulic investigations, without exception, the mass set in motion either increases or diminishes along with the acceleration, or in case of constant acceleration, is itself variable. The first case corresponds to constant section profile and variable head; the second to constant head and variable profile. We therefore err, if we infer an equilibrium of accelerating and retarding forces, from the fact of constant velocity in the motion of water. Motion under the operation of constant forces may be continually varied as well by setting new masses in motion with constant velocity, as by giving to the same mass a constant increment of velocity. The first case corresponds to the motion of water in tubes, and discharge from orifices of vessels; and the continually acting surplus of accelerating force in this case produces a determinate and constant work, since during each unit of time a velocity, v, is imparted to a mass, Q, which was at first at rest in the vessel. Where, hitherto, we have understood v to mean the constant velocity of a uniform volume in motion, we really had to do with nothing more or less than the acceleration p, of a constant force, P. To this change of conception correspond the device of making the resistance increase as some power of the velocity, and the assumption of a new error to compensate for the former.

Still, within certain limits we have approached very near the true law by means of empirical coefficients, because we have generally worked with a certain head in the correct ratio to the acceleration; and with a certain limitation of length and section-profile of wet perimeter in a correct ratio to the retarding force.

Looking closely at the experiments which have been made during the last century by hydraulic engineers, with great labor and generous outlay of means, and especially at the measurement of the resistance of the walls of pipes, we must reach one conclusion. There was need only of a smooth tube with small orifice, set exactly perpendicular to a lever or spring balance. Let streams of water which fill the tube and flow with different velocities pass through it; then the index must show exactly in pounds and ounces the amount of cohesion and adhesion; in other words, the resistance offered by the tube.

With the conviction that the resistance increases in a direct ratio with the length of the tube, we come to the law of motion of fluids in channels of indefinite length. If we find our hypothesis for flow through tubes in agreement with the general law of Nature to the same extent as in the previous case of a supposed constant surplus of force, which acts in a discharging vessel so as to maintain a constant motion, we meet with the inexplicable anomaly that the water which runs uniformly, already has this velocity at the entrance of the channel. Hence we may look upon this case as the continuation of a motion already existing, without loss or gain of mechanical effect.

Dubuat's principle, that "when water moves uniformly in open canals, the resistance is equal to the moving force of the water," was obvious, so that it needed no demonstration. But the total moving force of water in a channel of length l, relative fall $\frac{h}{l}$, and section profile a, is entirely independent of the length, since it may be expressed as that of a heavy body on an inclined plane; *i. e.*, it equals $a\,l\,\gamma$ sin. a or $a\,l\,\gamma\,\frac{h}{l}$, $a\gamma h$, while the force of resistance is a function of the length l of the form $\mu\,\frac{a}{l}\,.\,l$. What significance must nature have to one who can represent this false relation by a certain and determinate variability of the factor $\mu\,\frac{a}{p}$, or of the quotient $\frac{h}{l}$. It is possible that in a single case, calculation would give a true result; but the probability of this is so small, that it is doubtful whether in all Europe there is a single stream that would give such a correspondence. So in following up to the present time the methods of determining a velocity formula, which will answer for all channels of indefinite length, we find that the search is for a law that cannot exist without contradiction of our ideas of natural forces which we have derived from experience. In this respect we find that the old French authorities followed a much more correct method than their successors; for in the well-known 31 experiments of Dubuat at Courpatel, at Yard, and on the Haine, we find exact length dimensions given, while these get no attention in modern experiments. Even the latest results of Humphreys and Abbott on the Mississippi, do not give length dimensions, and are therefore without value for the further development of the science.

A second circumstance—which is of more import in the motion of water in tubes than in river-channels, and of little consequence in the discharge from vessels, and which impairs the usefulness of all results from experiments hitherto—is the effect of temperature upon the resistance to fluid motion, an effect so far unknown.

The question whether this is a problem admitting of exact solution, must be decided in the future. There remains to be solved another problem, seeming at least still to be more difficult of solution, before hydraulics can become an exact science; that is, finding the relation of the work of resistance to accelerating force and to acceleration. We find nothing analogous in the whole range of mechanics, to assist in the determination of this relation. We go beyond our original intent in this article for a brief consideration of this subject.

Let us assume that water flowing from a vessel, A, into a vessel, B, with a level lower by h, through a tube of length, l, section a, and wet perimeter, p, is subjected to an accelerating force $P = a\,h\,\gamma$, and to an opposing retarding force, R, smaller than P. The excess P—R causes a certain discharged mass $m = \frac{a\,v\,\gamma}{g}$ during each unit of time to change from rest to motion and to acquire the velocity v. Hence we have the fundamental equation $v = \frac{P - R}{m}$ (1) *i. e.*, the algebraic sum of the forces divided by the mass.

Now let us assume that it is possible to measure and express in numbers the total internal and external work of resistance performed by the water while discharged through the vertical tube fixed to a balance as above described, and to represent it as the product $A_r = W\,v$ of a certain resistance, W, and the mean resistance of the water; then the problem of finding v from equation (1) would seem to be solved if we could express the unknown resistance, R, which P opposes, to the mass m, by $A\,r$. It may be asked, what can this R be other than $\frac{A_r}{v} = W$,

the resistance that describes a path, v, in a unit of time?

This ideal force R, which we will suppose to be measured by an ideal acceleration, r, which it can impart to the mass m, is not = W, but we have

$$R = \sqrt{2\,m\,A_r} = \sqrt{2\,m\,W\,v}. \qquad (2.)$$

That is, it must fulfil the condition, that its effect upon the motion of discharge during each infinitesimal time element, $d\,t$, shall destroy the work of resistance or generate its equivalent. If this work, during the time-unit is $A\,r$, and is proportional to the space described in the same time by the discharged mass, then, during the time $d\,t$, the work is $A_r\,d\,t$; but the work done by the force, R, is that which gives a mass, m, a final velocity, r, that is $\frac{m\,r^2}{2}$, hence for the time, $d\,t$, $\frac{m\,r^2}{2}.d\,t$; since r and v must be regarded as constants, and the mass discharged as the only variable equivalent to the product of section velocity, and time.

Equating both expressions for work, we have

$$A_r\,d\,t = \frac{m\,r^2}{2}.\,d\,t.$$

or

$$A_r = \frac{m\,r^2}{2} \qquad (3).$$

which holds for any time, and therefore for the time-unit. But since $R = m\,r$ substitution in (3) gives

$$R = \sqrt{2\,m\,A_r} = \sqrt{2\,m\,W\,v},$$

which was to be proven.

If we obtain the coefficient of resistance ρ, by which $\sqrt{2\,g\,h}$ should be multiplied to give the effective velocity for every sort of motion, after finding the value of W, we have this relation to the cardinal equation, which solves all hydraulic problems.

$$\rho = \sqrt{1 + \frac{W}{4\,a\,\gamma\,h}} - \sqrt{\frac{W}{4\,a\,\gamma\,h}}.$$

Expressing the resistance of the wetted walls by $\mu\,p\,l$, and assuming that μ at 13 deg. R, is 0.52 lbs. for the surface-unit of a square foot (Prussian standards), the work absorbed in overcoming resistance is $W = 0.52\,p\,l\,h\,\frac{2}{3}$, and is therefore a function of the head h, of the form h^x; and, contrary to previous assumptions, is entirely independent of the effective velocity, V. With these formulas we find an agreement in the results of experiments which cannot be shown by any previous empirical formulas.

We thus obtain instead of Egtelevein's empirical formula for motion in canals and rivers, which is generally written

$$v = 90.9\sqrt{\frac{a\,a}{p}}$$

this formula

$$v = 86.08\sqrt{\frac{a\,a}{p}}\sqrt[6]{a\,l}$$

The small valuable factor $\sqrt[6]{a\,l}$, the difference of levels between A and B, explains why Egtelevein's formula has ordinarly (but by no means in all cases) given correct results, and approaches most nearly to the actual law.

CEMENT MANUFACTURE IN INDIA.

From "Engineering."

An order has recently been issued by the Governor-General of India on the subject of cement manufacture in that country, from which it would appear, at first sight, that no important works requiring anything more than ordinary mortar had ever yet been constructed there, excepting with cement obtained from England. What, however, we may ask, is to be said with reference to the old buildings, Hindoo, Mahomedan, Dutch, and Portuguese, all over India, under all varying circumstances and climates, which have been constructed with so excellent a cement that the masonry will break anywhere rather than at the joints, although the bricks, as well as the mortar, are stronger than any that are made now? Then, again, even since the British occupation of India, there are to be found works in the construction of which hydraulic and other cements have been required to be used, and which have hitherto stood the test of time, and may, therefore, be presumed to have been efficient for the purposes for which they have been employed. It is true that recently, and especially in the military department, it

has been customary for buildings erected at enormous cost to fall down almost as soon as built, and the defective part of the construction has generally been the cement used. The exposures, however, which have taken place in connection with some of these failures tend to prove rather that the causes of them have been, not the absence of all knowledge of how to make cement in India, but rather the existence of a reign of negligence, corruption, and adulteration, coupled also occasionally with incapacity. The remedy for these defects is, therefore, not the introduction of a new and improved manufacture of cements in India, but the eradication of those evils from the Department of Public Works to which we have just referred.

Had there existed no publications in India on the subject of native cements used on her public works, there might possibly be some slight excuse for the officers of the secretariat, supposing that the art of cement manufacture had been already lost to India; but even that fact would not be sufficient to excuse the chief officers of the executive branch of the Department for their want of knowledge in that respect, for surely a knowledge of cement manufacture must in every country constitute one of the most important branches of knowledge of the civil engineer, and more especially is this the case in a country like India, where very often, in the case of large works, all the cement required has to be manufactured on the spot, all the lime burned, and all the bricks required made under the immediate superintendence of the engineer in charge. Departing now from speculative considerations, let us see what information may be derived from Indian publications, a reference to which might perhaps save the several local governments from the necessity of appointing officers specially to discover for them what has already been published. We have not thought it necessary to search back very far, confining ourselves strictly to well-known professional works, in order to arrive at an amount of information on this subject which will doubtless be found of much value and interest to those concerned in the construction of public works in India. At vol. i. of the "Professional Papers of the Madras Engineers" (published in 1839), pages 28 *et seq.*, will be found an interesting account of the manufacture and use of magnesia cement. In order to form the cement, the stone should first be broken up into small pieces, and then placed in a kiln to be calcined. During calcining the heat must not be raised to too high a temperature, otherwise the outside of the magnesia will melt, while the inside remains only half burnt. The most important thing, however, appears to be that the stone should remain in the kiln for at least 24 hours. After being thoroughly burnt, it should be pounded and sifted, and mixed with 1½ or 2 parts of sand. It must be thoroughly mixed with the sand while dry, and then moistened. "It will set in some degree in 2 or 3 hours, and become hard in a few days, after which it will continue still to harden, though slowly, for many months, or probably years." Some plastering, tried at the Cauvery Anicut by Captain (now Sir) A. T. Cotton, "became in a fortnight harder than any stone, except granite, marble, and stones of the first degree of hardness." Captain Cotton, in 1837, made a great variety of experiments with magnesia cement, using stone from various quarries, and with different proportions of sand, and other materials. Almost every one of them formed an excellent cement, setting generally in 1 or 2 hours sufficiently to be secure from the effects of water passing over it, but if plunged imediately in water, before it had begun to set, it would not set at all. It was observed by Captain Cotton that stone taken fron the surface of the ground was all extremely hard, while in general that found below the surface was much softer, though apparently equally pure, but hardened by exposure to the air; the cements made with the under stone were not found to give such good results as when surface stone was used. A mixture of iron ore with the magnesia in equal parts, both finely pounded and sifted, was found to make the strongest cement, and a mixture of lime and ironstone with the magnesia was also found to form a very hard cement. In forming cubes of brickwork, the magnesia cement was found to set very rapidly, "and in a few months it became so hard that it was impossible to separate it from the bricks; however small the cube was broken up, the bricks were always broken, without the cement being separated from them." A mixture of lime makes the cement less liable to crack when used as a plaster, but it will not set so hard.

In September, 1835, a committee was formed of engineer and medical officers at Madras, to examine a supply of calcined magnesia received from Salem, and to report on its fitness for building purposes. In their report it is stated as follows:

"The committee carefully examined portions of the magnesia cement on the walls of the superintending engineer's office, and on the sea face of the fort (in one of which, prepared from 3 parts, by measure, of sand, and 2 of the last supply of magnesia, salt was employed without injury), and find that they had acquired a great degree of hardness, although not fully equal to some specimens prepared from a former supply, which had been longer exposed to the air, and which had attained an extreme degree of hardness. It would appear, also, that a proportion of sand, amounting to about 1½ parts, by measure, to 1 of magnesia, increases the usefulness of the cement for general purposes, bnt that this proportion may be increased or diminished, according to the view with which it is employed. When applied as an hydraulic cement it should not be subjected to water for upwards of 12 hours from the time of its application."

Turning now to the "Roorkee Treatise on Civil Engineering," vol. i., page 70, we find that Major H. A. Brownlow, R.E., Superintendent Eastern Jumna Canal, in a case where some urgent repairs were required, made a most excellent cement from the stone lime and brown alluvial clay procured near the head of the canal, following General Pasley's rules for mixing and calcining. Hydraulic cement has also been made with considerable success in Madras and at Singapore. Lieutenant Morgan on the Eastern Coast Canal, 6 miles north of Madras, made cement of 7 measures of shell lime to 5 measures of clay, following closely Pasley's rules for mixing and burning it. If applied under water this cement hardened in 24 hours; if applied dry and water let on it in half an hour, it hardened in 8 or 10 hours. The same cement mixed with an equal quantity of soorkhee (pounded brick) hardened in 48 hours under water, or in 12 to 24 hours if allowed half an hour before the water was let on it. Captain Man, at Singapore, found he could make a similar hydraulic cement, of excellent quality, using 5 measures of slaked lime to 2 of fresh blue clay. Natural hydraulic lime may be made from all the kunkurs found in India, but they will of course be found to vary in character with the different proportions of clay found in their composition. It is a common practice in India to mix a small quantity of the coarsest sugar ("goor," or "jaghery," as it is termed in Madras) with the water used for working up mortar, and to this is attributed the fact that mortars made of calcined shells have stood the action of the weather for centuries, from their having this mixture of "jaghery" in their composition. Captain Man made experiments on bricks joined together by mortar consisting of 1 part common shell lime to 1½ sand. 1 lb of jaghery was mixed with each gallon of the water with which the mortar was mixed. The bricks were left for 13 years; and after that time the average breaking weight of the joint in 20 trials was 6½ lbs. per sq. in. In 21 specimens joined with the same mortar, but without jaghery, the breaking weight was 4½ lbs. per sq. in. In the jaghery mortars the cohesion and adhesion were nearly equal; in the other the former was nearly double the latter.

In Sir Proby Cautley's admirable work on the Ganges Canal, he has not omitted to record the nature of the cement used by him in that undertaking. Referring, then, to that publication for the desired information, we find that in the construction of the Myapoor works, boulder masonry was laid with a cement composed of 1 part stone lime, 1 part soorkee, and 1 part sand, whilst with brick masonry the cement used was 1 part stone lime, and 1 part soorkee, and the whole of the works were stuccoed with a cement formed with the latter ingredients, and in the same proportions. In the Rutmoo works, which are built wholly of brick, the lime used in the cement was made from lime rock either burnt in the Dehra valley, or from lime boulders collected in the bed of the Ganges. The proportions of material used in cement were as follows:

Mortar		1 part stone lime, 2 parts soorkee.
Plaster	Inlet and dam piers	1 part stone lime 2 parts soorkee.
	All the rest of the work	3 parts stone lime. 2 parts soorkee.

Similar statements occur in the various parts of the Ganges Canal Report, vol.

ii., and in the third volume is a statement of the entire amount of lime used on all the canal works. In some experiments made at Roorkee to discover the best composition for an hydraulic cement, the bricks, the day after being joined, were placed at the bottom of the Ganges Canal, and exposed to a stream of nearly 3 miles an hour. The cements were made of old fat stone lime, which had been lying under a dry arch for 6 years since being burnt; this was slaked, mixed with 1½, 2, and 2½ times its own weight of ordinary brown clay, following Pasley's directions. The composition of 1 lime to 2 clay was found the best, and 1 lime to 2½ clay the worst. At the same time some fresh stone lime was ground and mixed ed up carefully with an equal bulk of ground soorkee; and the result of a number of experiments proved that although the mortar made of lime and soorkee set in the air as hard as that made of the lime and clay burnt together, yet it would in no case set when exposed to the force of the canal stream; while the cement after 14 days under water required a breaking weight of 10 lbs. per sq. in. to separate the bricks. Some very hard blue clay was afterwards obtained from Hurdwar, and mixed with fresh stone lime, very slightly, if at all, hydraulic, in the proportion of 1 lime to 2 clay; and balls were calcined and ground as before; of this cement 4 prisms were made 6 in.×2½ in.×2½ in., and after 26 days immersed in water were subjected to a transverse strain the bearing being 4 in. The average breaking weight of the prisms was 598.5 lbs.; the greatest being 675 5 lbs. This gives the value of C, the constant of strength for this cement=123, while for prisms of Roman cement 11 days old was only 150. The lime used in that part of India is derived from 3 sources: 1, boulder limestones found in the beds of hill torrents; 2, marl, or earth lime, as it is called; 3, kunkur lime. Analysis of the first two varieties:

Nature of lime.	Moisture expelled at 212°.	Organic matter and moisture.	Silicious matter and clay.	Carbonate of lime.	Carbonate of Magnesia.	Oxide of iron and alumina.	Total.
1. Marl lime.	1 44	1.27	49 80	37.01	2 79	7 69	100
2. Stone lime.	0.40	2.43	11.18	50.43	23.78	11 83	100

The kunkur lime is similar to No. 2, both differing widely from stone lime. All make excellent mortars for hydraulic works; the ordinary mixture with No. 1 lime being 1 part stone lime to 2 of soorkee, or 140 lbs. lime to 400 lbs. soorkee, and if the mortar is to be used for ordinary building, 1 lime, 1 soorkee, and 1 sand may be used. With the marl lime, 1 of lime to 1 of sand, without any soorkee, is used.

Part of the foregoing particulars is taken from vol. iv. of the "Professional Papers on Indian Engineering," published at Roorkee. At page 192 of the same volume we find an account of the process of manufacture of artificial hydraulic lime on the Kurrachee harbor works. Ordinary rich lime slaked to powder, is mixed with clay, in the proportion of 5½ parts, by measure, of lime, to 1 part of clay. The rich lime used in the harbor works has been generally made from the hard crystalline limestone procured from the Giznee hills, near Kurrachee (shell-lime would probably be found a tolerable substitute where limestone is not easily available). The clay is procured *in situ* from the bed of the Lyaree river, and is of the description that might be used for bricks or coarse pottery. The mixture of the lime and clay is made in a mortar pan worked by steam power, a sufficient quantity of water being added to bring it to the consistency of a stiff mortar. The mixture is then made by hand into balls of about the size of a large orange, which are laid out on the ground to dry in the sun. When thoroughly dried, which takes from 2 to 6 days, according to the weather, the balls are burned in a kiln; or if the lime is not likely to be soon required, they are stored in a shed. It is most important that the balls should be thoroughly dried before burning."

Vol. v. of the same series of "Professional Papers," contains, at page 385, an account of experiments on mortar made by Lieutenant J. L. L. Morant, of the Royal (Madras) Engineers, during the construction of the masonry forts in Bombay Harbor. We have already stated enough to show that information does already exist, in an available form, as regards the limes, mortars, and cements of India; it will not therefore be necessary to follow out these experiments here. The fact is—not that the information recently called for by the Indian Government is wanted;

but rather the means of enforcing more vigilance in the inspection of materials obtained by contract for building purposes, so that fraud and adulteration may be certain of detection and punishment; that incapacity in the Executive may meet with its proper reward; and that neglect of duty may not be practised with impunity.

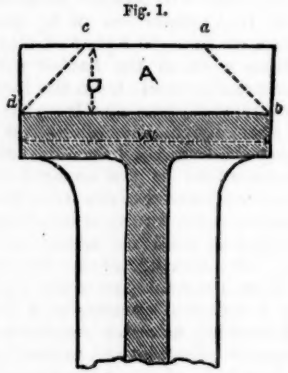
STRENGTH OF SPUR WHEELS.

By FRANCIS CAMPIN, C. E.

From "The Artizan."

In the present paper we purpose making some remarks upon the strength of mill-gearing, in order to set forth the principles upon which machinery of this description should be designed.

Fig. 1.



Let A, Fig. 1, represent a section of the rim of a spur-wheel taken over one of the areas, it is required to calculate the strength of the teeth of the wheel.

According to the old fashion it has been customary to calculate the strength on the line *a*—*b*, or *c*—*d*, as the whole strength of the wheel; but if this were correct, the lines being at an angle of 45 deg. to the face of the wheel, it is evident that it would be useless to make the width more than twice the depth of the tooth.

It is well known, however, that wheels very commonly lose the corners from their teeth and yet continue to work well for years afterwards. In point of fact, the tooth of the wheel is a cantilever, and its theoretical form should be to taper in width from its base *b d* to its point. Although we have heard it asserted that the strain upon the tooth of a wheel is neither more nor less than a shearing strain—a statement which is fallacious on the face of it, as the strain must be of a bending nature, and the maximum strain being reached when the power is being transmitted through the extreme end or point of the tooth.

It is found that a cantilever of cast iron, 1 in. long, 1 in. wide, and 1 in. thick, breaks under an extreme load of 8,000 lbs.

To find the breaking weight of any given cast-iron cantilever loaded at the end:

Multiply the breadth in inches by the square of the thickness in inches, the product by 8,000, and divide by the length in inches.

Let w = breadth in inches.
D = length "
t = thickness "
W = breaking weight.

$$W = \frac{8{,}000 \times w \times t^2}{D}.$$

Example: Let $t = 2$ in., D = 3 in., $w =$ 6 in.

$$W = \frac{8{,}000 \times 6 \times 2^2}{3} = 64{,}000 \text{ lbs.}$$

breaking weight.

In practice it is usual to make the working strain one-sixth of the breaking weight;

Let L = safe load.

$$L = \frac{8{,}000 \times w \times t^2}{6 \times D}$$

$$= \frac{1{,}333 \times w \times t^2}{D}.$$

Therefore

$$t^2 = \frac{D\,L}{1{,}333 \times w}$$

$$t = \sqrt{\frac{D\,L}{1{,}333 \times w}}.$$

Which is the proper rule for calculating the thickness of the teeth of spur wheels.

Let the force transmitted by a spur wheel be 10,000 lbs., the length of the

teeth being 3 in. and the breadth 6 in., then—

$$t = \sqrt{\frac{D\,L}{1{,}333 \times w}} = \sqrt{\frac{6 \times 10{,}000}{1{,}333 \times 3}}$$
$$= \sqrt{15} = 3\,87 \text{ in.}$$

It is, however, in many cases more convenient to calculate at once the pitch of the wheels instead of the thickness of teeth.

According to the Manchester scale the thickness of a tooth is equal to 0.45 pitch. Therefore, if P = pitch

$$P = T \times 2.22.$$

Therefore

$$P = 2.22\,t = 2.22\sqrt{\frac{D\,L}{1333 \cdot w}}$$
$$= \sqrt{\frac{5\,D\,L}{1333 \cdot w}} = \sqrt{\frac{D\,L}{266 \cdot w}}.$$

Let the force transmitted by the wheel be 4,000 lbs., the length of tooth 2 in., and the breadth on face 4 in., then the pitch will be thus found—

$$P = \sqrt{\frac{D\,L}{266 \cdot w}} = \sqrt{\frac{2 \times 4000}{266 \times 4}} =$$
$$\sqrt{7.5} = 2.73 \text{ in. pitch.}$$

If we could be always certain of having the wheels very accurately made, it would not be necessary to make one tooth carry the whole strain ; but as this exact workmanship cannot always be secured, we have for the sake of safety to consider the whole strain as possibly coming on the point of one tooth, and make the wheels strong in proportion.

We must now make a few remarks as to the shrouding of wheels. In this case we have undoubtedly, in addition to the strength of the tooth regarded as a cantilever, the resistance to shearing at each end where the tooth joins the shroud. Let us assume the teeth to be shrouded on both sides up to the pitch line, that is half way up.

Taking the first example where $t = 2$ in., $D = 3$ in., and $w = 6$ in., we found—

$$W = \frac{8{,}000 \times 6 \times 2^2}{3} = 64{,}000 \text{ lbs.}$$

breaking weight merely regarding the tooth as a cantilever. Now, we have shearing area to the extent of half the length of the tooth multiplied by its thickness and by 2, there being a shroud on each side of the wheel ; hence the shearing area will be—

$$1.5 \times 2 \times 2 = 6 \text{ square inches.}$$

Taking the shearing resistance of cast iron at 17,000 lbs. per sectional square inch, the additional resistance afforded by the shrouding will be—

$$17{,}000 \times 6 = 102{,}000 \text{ lbs.}$$

or nearly twice the strength of the tooth itself.

In any case it may safely be assumed that shrouding the teeth double their strength, and in most cases it does more than this.

Having determined the strength of the teeth, it becomes necessary to find a law for the strength of the arms of wheels through which the strain is transmitted from the rim to the shaft, or *vice versâ*.

It will be observed that the strain will not be constant on all the arms, as those nearest to the teeth in action will be the most strained, and the strain will diminish on the following arms, so that the strain on any one arm will always be varying.

If the rim of the wheel were perfectly hard and inelastic it stands to reason that the strain would be equal on all the arms, but this not being the case the strains vary according to the compression or extension of the rim.

For all practical purposes we may assume that the maximum strain that will come on one arm is one half of the total transmitted strain. Let the force transmitted be 10,000 lbs. on the teeth of the wheel, then on any arm there may come a force of 5,000 lbs., tending to break it like a cantilever.

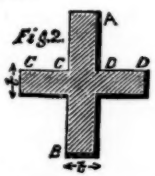


Fig 2.

In Fig. 2 is shown a section of an arm, but it might, of course, be of square, circular, or other section.

The direction of pressure is from A to B, or from B to A, and the force according to discretion is regarded as being withstood by the whole section, or by the parts A B only ; in the latter case the webs C C, D D, only act as lateral stiffeners to the wheel.

We will act upon the latter assumption; then A B is the depth of the cantilever, and its length is equal to the distance

from the outside of the boss to the pitch-line of the teeth.

Let the length of the arm be 20 in. If W= the force acting at the end of the arm, t the thickness, d the depth, and l the length, then for the breaking weight we find—

$$W = \frac{8000\, t\, d^2}{l}$$

all the dimensions being in inches, and the force in tons.

And if the safe working load is taken at one-sixth of the breaking weight the formula becomes—

$$W = \frac{1333\, t\, d^2}{l}$$

from which the formulæ for depth and thickness are obtained.

$$t = \frac{W.l}{1333.d^2}$$

$$d = \sqrt{\frac{W.l}{1333.t}} = 0.027\sqrt{\frac{W.l}{t}}$$

In the foregoing cases assume the depth of cantilever, or width of arm at the boss, as 8 in., then, the safe load being 5,000 lbs., and the length 20 in., we have for the thickness—

$$t = \frac{W\ l}{1333.d^2} = \frac{5000 \times 20}{1333 \times 8 \times 8}$$

$$= \frac{100000}{85312} = 1.17 \text{ in.}$$

This applies to wheels having 4 arms.

If the wheel has 6 arms we may assume the maximum strain on any arm at one-third the total load, and the thickness would be—

$$t = \frac{W.l}{1333.d^2} = \frac{333 \times 20}{133 \times 8 \times 8}$$

$$= \frac{66666}{85312} = 0.78 \text{ in.}$$

Suppose, however, in the first case (4 arms) it is decided to make the arms 3 in. thick, the requisite depth will be—

$$d = 0.027\sqrt{\frac{W\ l}{t}} = 0.027\sqrt{\frac{5000 \times 20}{3}}$$

$$= 0.027\sqrt{\frac{100000}{3}} = 0.027\sqrt{33333}$$

$$= 0.027 \times 183 = 4\ 94 = \text{(say) } 5 \text{ in.}$$

This then will be the requisite width of the boss, whence it may be diminished by any suitable taper down to the rim of the wheel, for the strain upon the arm is at its maximum where the arm joins the boss, and then diminishes to *nil* at the pitch circle of the teeth, and the strain on any part of the arm is in direct proportion to the distance of such part from the pitch circle. Thus at the centre of the arm the strain is half as great as at the boss, and so on.

For a different number of arms it may be generally assumed that the strain at a maximum on any arm is equal to the total force divided by half the number of arms.

Let P = pressure on teeth.
n = number of arms.
W = maximum load on any arm.

$$W = \frac{2\ P.}{n}$$

Let P = 5600 lbs., n = 5 arms,

$$W = \frac{2\ P}{n} = \frac{2 \times 5600}{5} = 2240 \text{ lbs.}$$

The parts of the arm shown at C C, D D, in Fig. 2, do not add much to the strength of the arm to resist the stress of which we are now treating, as they lie too near to the centre or neutral axis of the cantilever.

Thus if these portions be 2 in. square each, they will together be equal to a solid cantilever 4 in. wide and 2 in. deep, and the portion A B has been shown to be 5 in. deep and 3 in. wide.

The transverse strength of solid beams (rectangular in form) varies as the breadth and as the square of the depth.

Let $b\ d$ represent the breadth and depth of one beam.
B D represent the breadth and depth of one beam.
R represent ratio of strengths.

$$R = \frac{b.d^2}{B.D^2}$$

in the present instance,

$$R = \frac{b.d^2}{B.D^2} = \frac{4 \times 2 \times 2}{3 \times 5 \times 5}$$

$$= \frac{16}{75} = 0.21, \text{ or nearly } \tfrac{1}{5}.$$

There is another matter to be considered in connection with wheels, which is the effect of certain strains common to all rotating bodies, and caused by the centrifugal force which the rotation calls into action. This force acts primarily in a radial direction, but it may be resolved into tangential force; hence the intensity of it in its direct action can be ascertained.

First we will consider the rim of the wheel—

Let v = velocity of periphery in feet per second.
n = number of revolutions per minute.
d = diameter in feet.

w = weight per foot of rim in lbs.
a = sectional area of rim in sq. in.
c = centrifugal force in lbs.

Then for one foot of the rim we find—

$$c = \frac{w \times v^2}{16.1 \times d}$$

from the ordinary formula for centrifugal force.

We will treat this as a simple radial force tending to burst the ring, and call S the tensile strain on any section of the rim—

$$S = \frac{c\,d}{2}$$

but from the foregoing equation,

$$d = \frac{w \,.\, v^2}{16.1 \,.\, c}.$$

Wherefore

$$S = \frac{c}{2} \times \frac{w\,v^2}{16.1 \,.\, c} = \frac{w\,v^2}{32.2}.$$

Then allowing 1,800 lbs. per square inch as the tensile working strength of cast iron the sectional area of the rim should be—

$$a = \frac{w \,.\, v^2}{32.2} \times \frac{1}{1800} = \frac{w\,v^2}{57.960}$$

But from the specific weight of cast iron it is found that—

$$a = \frac{w}{3\,2}.$$

Also,

$$n = \frac{60 \,.\, v}{3.1416 . d} = \frac{19 \,.\, v}{d}.$$

And therefore,

$$v = \frac{n \times d}{19}.$$

Whence by replacing in the various equations we deduce the limiting velocity for a cast-iron wheel working safely

$$n = \frac{2546}{d}.$$

NOTE.—For a wrought-iron rim it would be—

$$n = \frac{4427}{d}.$$

In the next place the strength of the arms to resist centrifugal force must be considered, as if the rim be flawed it will be held by the arms alone. The portion of the periphery of which the centrifugal force should be sustained by one arm, is that part lying between two arms.

Let a = sectional area of rim in square inches.
d = diameter of wheel in feet.
v = velocity in feet per second of rim.
A = area in square inches of one arm.
N = number of arms in the wheel.

Then because a 1 in. square bar of cast iron 1 ft. long weighs 3.2 lbs., the weight of the rim is

$$W = a \times 3.2 \times 3.1416\,d = a \,.\, 10 \,.\, d.$$

Hence the centrifugal force on all the arms may be

$$c = \frac{W\,v^2}{16.1 \times d} = \frac{10 \,.\, a \,.\, d \,.\, v^2}{16.1 \times d} = \frac{a\,v^2}{1.6}$$

But

$$v = \frac{n \times d}{19}$$

hence

$$c = \frac{a\,(n.d)^2}{577.6}.$$

The safe resistance of all the arms will be—

$$= A \times N \times 1800,$$

hence

$$1800 \,.\, A \,.\, N. = \frac{a\,(n.d)^2}{577.6}$$

$$A = \frac{a\,(n.d)^2}{1{,}039{,}680 \,.\, N}.$$

From these formula we can, for example, find the highest safe velocity at which the foregoing wheel could be run. The length of one arm being 20 in., its diameter would be 4 feet—

$$n = \frac{2546}{d} = \frac{2546}{4} = 636.5 \text{ revols. per minute.}$$

It is but seldom that spur wheels are run anywhere near their limiting velocities, but it is nevertheless necessary to consider the possibility of such cases arising.

As we have already observed, much depends upon the workmanship put into wheels, and before calculating for heavy mill work it is always advisable to inform ourselves of the average quality of work we may obtain.

Before concluding the present paper we will enter briefly upon the method of determining the maximum pressure on the tooth of a spur wheel.

It is very improper in all cases to calculate from horse power, for it may happen that at a certain position of the pistons the strain is much above the average

The moment of strain upon a revolving shaft is found by multiplying the strain by its distance from the centre of revolution.

Let the piston of an engine have a diameter of 20 in., then its area will be

$$= 314 \text{ square inches.}$$

A maximum pressure of 40 lbs. per sq. in. would give as gross pressure

$$314 \times 40 = 12{,}560 \text{ lbs.}$$

Let the crank be 2 ft. long, then as this force can never act at a greater distance from the centre of rotation than the length of the crank, the maximum moment will be

$$12{,}560 \times 2 = 25{,}120 \text{ foot lbs.}$$

If there be keyed on the engine-shaft a wheel of 4 ft. radius, the greatest pressure given off by one of its teeth will be found by dividing the moment of force by the radius,

$$\frac{25120}{4} = 6280 \text{ lbs.}$$

will be the maximum force on one tooth.

The pressure on one tooth of a driven wheel is the same as on one tooth of the driver.

If there are two spur wheels on one shaft—one (w) receiving motion and so communicating it to the shaft, and the other (W) giving it off to a fourth wheel, if p be the pressure of the teeth of w, and r and R the respective radii of the wheels, then the pressure P on the teeth of W will be thus found,

$$P \times R = p \times r$$

because the power being transmitted through the shaft unaltered, the moments of stress must be equal at both points of reception and distribution, hence

$$P = \frac{p \cdot r}{R} \text{ or } R = \frac{p \cdot r}{P}.$$

THE RAW MATERIAL FOR BESSEMER STEEL.

From the "Bulletin of the American Iron and Steel Association."

Although the manufacture of Bessemer steel has now become an established industry, the manufacturers are still confined to the use of ore of remarkable purity, and especially free from phosphorus; and taking advantage of the constantly increasing demand for ores of suitable quality, and the high prices obtained for them, an influential company (to which reference was made in last week's "Mining Journal") has been formed for working some extensive deposits in Spain, and shipping the ore to the English markets. The mere fact of some of the largest steel manufacturers and consumers of the purer qualities of ore accepting seats on the direction of the Bilbao Iron Ore Company should alone suffice to convince the public that ore of the desired quality is not readily obtainable at reasonable prices, within reach of the works at home; yet there appear to be some who, in their energy to utilize our native minerals, go a step too far, and assume that the importation of foreign ores is objectionable, and should be altogether discountenanced. It was stated in the prospectus of the company in question that the ironsides of South Wales, South Staffordshire and Scotland, are becoming exhausted, insomuch that the necessary supply for these districts has for many years been supplemented by the hematite ores of Cumberland and Lancashire; but owing to the great and constantly increasing demand for hematite pig iron for admixture with iron made from inferior ores, and the extension of the Bessemer steel manufacture, nearly the entire produce of hematite ores is absorbed by the iron works in the Cumberland district alone, and the price of these ores has advanced within the last two years 70 per cent., and hematite pig iron for the Bessemer process 50 per cent.

To such a statement there can be no valid objection, and if the Bilbao Company can supply the iron-masters engaged in the Bessemer steel manufacture with ores analogous to the Cumberland hematites, and yielding from 50 to 60 per cent. of metallic iron, no doubt need be entertained as to the facility of finding a ready market for them. With a view to depreciate the merits of the enterprise, however, attention has been drawn to mines alleged to exist in the forest of Dean and the West of England, which were described as being a closer proximity and more readily available, capable of pro-

ducing superior ore, suitable for Bessemer pig iron; but fortunately Mr. Bessemer and Mr. Hardy of the Tredegar Iron Company, both equally unconnected with the Bilbao Iron Ore Company, have published the facts of the case. Mr. Bessemer knows the mines and the ore they produce; yet he writes that the Bilbao Iron Ore Company would have more correctly described the condition of the trade by stating that the greatly increased production of Bessemer steel has, within the last two years, doubled the price of hematite ore in England, and also greatly increased the price of pig iron made from it, and that the development of the Bessemer steel trade would be immensely increased by the introduction into the English market (at a moderate cost) of a further supply of hematite ore from Spain, a fact which Mr. Bessemer (being wholly unconnected with the Bilbao Iron Ore Company) can, without hesitation, most emphatically indorse; nor does he hesitate to affirm that the construction of a railway and a line of steamers connecting these magnificent mines with our own country, will be of almost incalculable benefit both to the steel and iron trade of the kingdom; while Mr. Hardy asserts as the result of his experience, that the chief supplies from the Forest of Dean and Cornwall are very poor ores, yielding only 30 to 35 per cent. of iron. This view is confirmed by Mr. Mattieu Williams, who explains that it is well known that for Bessemer purposes a pig iron especially free from phosphorus is required, and that all our ordinary ores, which have been deposited about organic nuclei, or are otherwise contaminated by the remains of fishes and other animal matter, are worthless for the manufacture of Bessemer pigs.

This is rather a serious fact for us, inasmuch as our supremacy as iron manufacturers has been mainly dependent upon the fact that wherever we have coal there is iron stone near at hand. But the same geological agencies which have deposited the organic matter of the coal, have contaminated the ironstones with organic phosphates. Our island, in spite of its general mineral wealth, is very poorly supplied with iron ores, that by their deposition among the more ancient rocks or otherwise are free from phosphorus. With the exception of little insignificant patches, we are reduced to a dependence on the Ulverstone district, and the vast development of the Bessemer demand is now rapidly working this out towards exhaustion. As to the Dean Forest hematite ores, it is very truly observed that they have been longer known and longer worked than any deposits of this class of ore in England; nevertheless, the total quantity raised in Dean Forest is under 200,000 tons per annum, while the amount raised in Cumberland and Lancashire exceeds 2,000,000 tons. If the Dean Forest deposits are so important, how is it that these ancient mines produce less than one-tenth of the ore raised in the modern northern mines? The importance of the Dean Forest deposits has, no doubt, been greatly exaggerated, while all that has been published greatly underestimates the vastness of the Spanish deposits, because the whole truth would but tend to engender incredulity.

It is gratifying to find that the ventilation of the prospects of the Bilbao Company has merely had the effect of increasing the rapidity with which the capital has been subscribed, Messrs. Chadwicks, Adamson, Collier & Co., by whom the subscription is issued, pointing out that, of the eight directors of the Bilbao Iron Ore Company, five are directly and largely connected with the manufacture of iron and steel, and know only too well the impossibility of finding in England deposits in the remotest degree approaching the power of giving adequate supplies. Of the remaining three, one is largely engaged in the sale of both English and foreign ores of this description, and another has been many years connected with one of the largest mercantile houses in the kingdom, and possesses an intimate knowledge of the Spanish language and of the value of Spanish ores.

During the past 5 years they have been consulted with regard to the sale of so-called hematite deposits in almost every part of the West of England, but have invariably found, on obtaining independent scientific reports upon them, that either they have been defective in the proportions of metallic iron, or that they existed in such situations as would place them at a great and permanent disadvantage as compared with other sources of mineral supplies. It is only necessary further to state, that Messrs. Lockhart, Tozer & Co., the sale agents of the Bilbao Iron Ore

Company, are enabled to assert that the various analyses of these ores prove beyond doubt that they contain as great a percentage of metallic iron, and fewer objectionable impurities, than the average North County hematites, and that as to price, Spanish ores have been sold this month in Cumberland at 26s. per ton, thus verifying the anticipation in the prospectus, "that the price of these ores must before long approximate more closely to the values of English hematites."

REPORTS OF ENGINEERS' SOCIETIES.

American Society of Civil Engineers.—At the first regular evening meeting, held the 6th u t., papers on "The Use of a Surface Condenser, with Blast Furnace Boilers," and "Well Boring in Connection with Deep Foundations," were read and discussed, and an apparatus, operated by hydraulic pressure, used in this city to take soundings along shore, down to bed rock or solid earth, was described; other important matters were also brought before the Society.

At the last meeting of the Society of Practical Engineers, an interesting paper was read by the President, James A. Whitney, on the different methods of Pneumatic propulsion.

Traction Engines.—At a recent meeting of the engineers of the branch association of Pomerania, at Stettin, Herr Topffer said that the 20-horse Fowler road engines, which during the late war had rendered great service, had returned to Cologne in a sound and good condition. During the seven months in which they were principally employed in completing the links between those lines of railway that had escaped destruction, they had dragged locomotives and tenders over hills and damaged roads, besides conveying heavy cannon and performing other transport services.

Professor R. R. Werner says that the Allen steam engine, with Porter's regulator, is much admired on account of its rapid and quiet action. A description of it was given, and it was favorably spoken of on the occasion of one of the meetings of the Magdeburg Association of Engineers. The theory of Porter's Regulator is discussed by W. Eckerth; and J. F. Radinger, in a treatise on steam engines with rapid stroke, illustrates the principle which underlies Allen's construction. "Zeitschrift," vol. vii. to vol. xv., illustrated.—G. Grillo describes his paper-cutting and shaping machine. He says that most of the machines at present in use cut perpendicularly, although the oblique cut is preferable in most instances. The worst feature of these machines, however, is that by cutting into the supports, the knives blunt quickly, thereby necessitating a constant grinding and re-setting. In his machine the knife only goes just through the paper parcel. Gadd & Moore's ribbon loom, and Willan & Mill's (Walmsley's patent) automatic shearing machine are favorably noticed. Hemp is specially recommended for stuffing-boxes. A manufacturer at Emmendingen (Baden), prepares the Rhenish hemp in ropes of ½ to 2 in. thick, and of as much as 300 ft. long.

At a recent meeting of the Midland Institute of Mining Engineers the following paper was read by Mr. H. Ogden:

On Exhaustion as a Power for Underground Purposes.—It is with considerable diffidence that I submit this paper to the members of this institute; but seeing that one of the objects of such meetings is to mention our experience in mining matters, and be willing to give as well as receive instruction—this must be my excuse for bringing this matter before you. Its importance or otherwise I leave entirely in your hands.

I have long been convinced that working engines by exhaustion, for underground purposes, is more profitable than by compression. My reasons for thinking so I will lay before you.

More than 20 years ago, at the Low Side Colliery, in Oldham, there were 4 engines working in the pit, being actuated, *i. e.*, motion given them, by one exhausted cylinder at the surface. Of course, the exhausting cylinder is nothing more than the compressing cylinder reversed—which, in the case referred to, was about 2 ft. 6 in. in diameter, and a stroke of, say, 5 ft.; it was fixed vertically, and worked by a beam from the connecting-rod end of a beam engine, about 20-horse power, which engine also drove the circular saws, a lathe, etc., for the requirements of the colliery. The exhausting cylinder gave motion to 4 vacuum engines at the pit bottom, 2 of which were placed a considerable distance in the workings, being coupled oscillating engines, 12½ in. diameter in cylinders; the others were single engines, and fixed at suitable parts of the mine for doing the haulage work of the mine generally.

My father had an engine works at the time, and made 2 of the vacuum engines. I, myself, erected one, and attended to the repairs of the colliery. I had opportunities of seeing the workings for a few years, and I can assure the members of this Institute that the engines worked extremely well. Scarcely any heat was set up, save at the two delivering valves at the exhausting cylinder which continually worked a little warm; neither were we ever plagued with ice. I may add, that the two coupled oscillating engines worked a very long jigbrow at first motion, which would be an inclination of about 1 in 4. The jigbrow was worked intermittingly, while the other 2 engines worked continuously.

I have noticed when there has been a heavy load drawing up the jigbrow, and all engines working at once, they did not go quite so fast, but still worked at a reasonable speed. These vacuum engines resemble steam engines, save that the slide valve is exposed to the atmosphere—consequently the drawing pipes are attached to what would be the exhaust pipe of a steam or compressed air engine; and the size of the cylinder of the vacuum engine can be arranged for the work you wish it to perform; *i. e.*, the motion parts of the vacuum engine do not require to be as strong, proportionately to the size of the cylinder, as they require to be for a steam engine. Let us consider what is the effect on the air, by contrasting the two systems, exhaustion *versus* compression. Mr. Warburton, in his paper, very ably describes the amount of heat set up by compression, and lost at the compressing cylinder, and it requires to be kept in remembrance that this loss takes place before your

compressed air has rendered you any service whatsoever, or is in a position to do so, and when used sometimes requires heat at the exhaust to prevent the formation of ice.

On the other hand, the effect with exhaustion is a great contrast; for the vacuum engines below are using the air at once, as fast as exhausted, and the engines are working cold, while the air delivered by the exhausting cylinder is warm, certainly, but nothing like the heat expended in the act of compressing the air; while the little heat contained in the air delivered at the exhausting valves, may be accounted for by its quick passage through, and friction in, the pipes connecting the vacuum engines below with the exhaust engines above; therefore a reverse action takes place, though, in exhaustion, heat is so small as to be easily accounted for. I gather, in my experience of exhaustion, that a transmittable power is produced for long distances, the most economical for mining purposes, being in ratio instantaneous; and consider, besides, that, for mining purposes, as is the depth of the mine so is the increased proportional or differential density of the air, which is all in its favor; and the denser the atoms are, in consequence of its weight and attraction, the easier it is to keep up a good workable vacuum. I certainly look upon exhausting engines as being a sound power, and one that requires the least attention of any that I know of. I am not aware that anything of this description has been practically carried out in this district or any other, except at the place and time named. If any of the members have used the principle, perhaps in discussion they will throw more light on the subject. I do not by any means assert that it is not understood, or claim it as my own invention; and it may seem to some to be a resuscitation of a useless principle; but from what I gathered from it in early youth, and the little that has yet been done with compression as a substitute, I consider it the most useful. Allow me to add that if I was using my own means for underground purposes, I should adopt the system by first having my fixed engines, which should be two coupled for exhausting purposes, at the surface, then my fixed vacuum engines, at the bottom, and a number of light removable vacuum engines, that could be fastened and used directly in any part of the mine.

IRON AND STEEL NOTES.

American Russia Sheet Iron.—A writer thus describes in a letter to the "Iron World and Manufacturer" the process of making polished sheet iron at McKee's Port, Pennsylvania: For ordinary sheet iron, the pig iron after puddling is converted into bars 5 in. wide, and is then cut into lengths of 28 in. and from $\frac{3}{8}$ to $\frac{5}{8}$ of an in. in thickness. These are conveyed to the furnaces to be heated for the rolls, on the railway alluded to, and piled up in stacks. But while the furnace men are waiting for the furnace already filled with these piles to come to a white heat, we will get into a safe place and watch the men at the rolls making bars. There are 4 of them to each set of rolls, and they are known by the euphonious names of "hook up," "catcher," "roller," and "dragout," names which distinctly indicate the office performed by each. Mr. "Dragout" stops at every chance and explains to us the peculiarities and the dangers encountered in rolling. He is a strong-looking fellow and seems to understand more about a rolling mill than simply to drag out bar iron. Every few moments a shower of fiery scintillations shoot out, filling a portion of the mill for an instant with a glow of fiery beauty. In puddling, the impurities in the iron often maintain a mechanical mixture. Under the tremendous pressure of the rolls it is compelled to leave the crevices of the iron in which it lodges, when they are compressed, and it does so in a fiery flood which makes the rollers hop suddenly out of reach. But there is the heater waiting on us to come and see.

The door is raised and a beautiful sight is presented. There, on the inclined surface of the heated coke lies a row of those short bars so white and bright-looking, as to appear like a row of transparent cocoanut candy slabs.

This is the pair furnace, so called because the bars are taken out in pairs to be rolled into sheet iron. It is a small square furnace, and is heated with coal and coke. From 36 to 54 pairs are laid side by side. There are 2 doors, one on the front for coke, one on the side for coal. The use of coal and coke generates a more intense heat than either separately, and the flame of the coal causes the heat of the coke to escape in a current more rapidly. The sides of the furnace are firmly secured by iron castings riveted and rodded together.

Another use of coal flame is to equalize the heat in the furnace, and thus prevent the gluing together of the plates which are subject to the action of the intense heat, and also to prevent the burning of the lower edges of the plates. From 20 to 25 min. are sufficient to heat them, and they are then ready for the rolls.

The heater turns a pair of them on his paddle the same way our great grandmother used to fill their ovens with bread. They are then drawn out and dragged to the rolls, spitting fire as they go.

The rolls are a curiosity; they are large solid cylindrical masses of iron, with a smooth surface, or grooved when desired, and for sheet iron manufacture are "chilled" to secure a hard smooth surface. "Chilling" is effected by pouring molten metal in iron vessels of the shape the roll is desired to be. The contact of the coal metal causes the more rapid abstraction of heat from the molten metal in contact with it, and hence it solidifies more rapidly than the inner portion, is more granular, tough and smooth. It is cast also with a slight arc, so that when the middle part of the surface of the roll is heated more than the outer edges, the expansion will fill up this arc to a straight line, and this makes the sheet iron of uniform thickness.

The thickness of the sheet iron is determined by the space between the rolls, and it is increased or diminished by means of a spanner wheel, which rests on a cog and pinions, elevating or lowering the upper roll. A dial plate attached to the wheel indicates the variations with the utmost precision.

The pieces are taken one at a time and sent under the roll sideways. The second follows immediately, and as they come, the catcher on the other side receives them and passes them as rapidly back over the top of the upper roll to the roller, who again passes them through until they are lengthened the necessary extent. The "spannerman" during this operation turns the wheel which lessens the space between the rolls. The wheel is 6 or 7 ft. in diameter, in order to give purchase enough to move the rolls easily.

When the plates are thin enough, he calls "double," and the roller then doubles the plates and passes them through. The upper plate is then lifted and a handful of coal dust is thrown in between, the object of which is to prevent the sheets from sticking together when passed between the rolls. The first process consists in "breaking down," in mill parlance, the plates in which they are made, 5 ft. long. Each third pair of plates are pressed about a foot shorter, and 1 of each is then placed between the other two pairs. This is called "mating," and each three are then called a "pack." These "packs" are then placed one by one in the heating furnace and re-heated to a red heat in about 2 minutes, and then returned and passed a number of times through the rolls, until they are 8 ft. long, in which operation the middle sheet comes out as long as the others.

If 4 or 5 sheets were run together instead of 3, the intense heat the inner ones would receive would cause them to adhere, and they could not receive the equal pressure of the rolls. In finishing, the upper roll is loosened from its couplings, and is permitted to rest its weight on the lower roll. The lower roll is driven by the engine, and the upper by the friction caused by its weight. The friction generates heat, which is carried off by a stream of water poured on the rolls after every third pair has been run. This is done to avoid the effects of the expansion of the rolls in the centre by heat, which, if permitted to take place, would make the sheet of uneven thickness, and even cut it in the centre.

After this, the sheets are placed on a car, and taken to the trimming room, where they are placed 6 in a pack, and the rough edges are sheared off by being made to come in contact with 2 smooth wheels, whose circumferences touch at one point.

They are then packed in large fire-proof air-tight annealing chests, 32 in. thick, and moved by machinery into the annealing ovens, where they are heated for 24 hours, and then permitted to gradually cool 24 hours, after which the sheet iron is ready for market.

The manufacture of the Russia sheet is not essentially different. After "breaking down," the sheets are removed to the washing room, where they are subjected to the action of certain acids, the object of which is to impart, after rolling, that bright glossy appearance which belongs to Russia sheet. The carbon is reduced in oil, because any other material would cause the iron to burn red before removing the sediment. No coal dust is used, as the carbon prevents any sticking. The polished surface is produced by friction in rolling. In "breaking down," the sheets are made 3½ ft. long, and in finishing they are increased to 5 ft.

Two large water tanks, 12 ft. in diameter by 8 ft. in height, supply the mill with water pumped from the river.

This is a model mill, and everything in and about it is indicative of clock-like precision and regularity. The firm are pressed with work, and their reputation as manufacturers of a superior quality of sheet iron has extended over the country. Its superiority is not any longer a matter of opinion, but a demonstrated fact. These works are a credit to Pittsburgh industries, and stand in the front ranks in sheet-iron manufacture. During the past 3 months, orders from every part of the country have been obliged to wait their turn because of the extraordinary demand; but at the present time they are about caught up, and are ready to supply all orders on short notice. Dealers and consumers generally would find it to their advantage to test the value of this sheet iron.

Devotion to the system of protection of which this industry is the product, commands us to look to home sources for supply.

The above firm are about erecting a $30,000 forge for the manufacture of charcoal blooms for sheet iron. Their facilities in the coming season will be such as to enable them to meet almost any demand which may be made upon them. This is saying a great deal, but it is in accordance with facts. American sheet iron, such as is made in their works, must take the first rank in the American market and the manufacturers of it are resolved that in quality and cheapness it shall be excelled by none, home or foreign. Tests of it fully establish the claims made for it. We have seen the foreign and home-made used side by side for months, and in appearance the home product is superior. It is brighter and smoother after long use. It is safe to assert that American skill will, when it obtains the control of this trade, improve upon the present process for manufacture, and invent new processes by which a still better article can be placed in the market at even lower than present prices. We assert this because in all other industries this is the tendency. We would rather rely upon American skill to cheapen a product than on foreign skill. But foreign cheapness does not benefit us in this case, because it is controlled by importers who put the price at the highest notch possible, regardless of its cost. The specialty of the above firm is Russian sheet, but the ordinary brand is manufactured to meet the market demand. We direct attention of users of sheet iron everywhere to the above establishment, and advise them to test its ability to supply a cheap and superior quality of sheet iron.

IRON INTEREST--ITS PROGRESS AND OBSTACLES.—The close of the year has not, in some respects, made as satisfactory showing for the iron interest as the bright prospects of its opening had given us reason to hope, but it is gratifying to know that this is easily accounted for, and the causes are such as to more fully assure us in our former estimate of the greatness and importance of this industry. Whilst we have not been as yet benefited by many of the results hoped for, it is now certain that the practical results will soon be reaped.

The most important branch of the iron interest is the blast furnaces, and it is to these we now refer. Their number has not been increased during the year, and the production of the stone coal furnaces is but little in excess of 1870. This is owing chiefly to the want of an adequate supply of fuel, and so far there is only one reliable channel of supply of the suitable quality. The inadequate demands of the market for the producing capacity of the furnaces, and, therefore, the excess of production, have caused lower prices here than in any other market, without any reduction whatever in the cost of production. Consequently, all the various manufacturing interests have prospered at the expense of the furnaces, and such is likely to be the case until the number and variety of the manufactures increase; but, notwithstanding this there is reason to hope that the next year will bring to the furnaces some important aid. Some of the railroads which are about finished, and others which are being constructed, will open at

least three additional coal sources, which will at once cheapen this very important item. One of these roads is of the 3 ft gauge, to run from opposite Carondelet through the Chester and Big Muddy coal fields. This will place these mines very near, and enable the furnaces to receive even the Big Muddy coal at a greatly reduced price. But the Chester coal is certain to become a competing coal for furnace use, and with a 3-ft. gauge road and the road leading from these mines to the river, it will have considerable advantage in transportation, and can be put down at Carondelet at almost the price of our ordinary coal. The southeastern road also runs through large fields of fine coal suitable for smelting purposes, and this road is also turning its attention to the development of the coal interests. There is also a proposed branch through the Columbia coal fields, which lie nearer Carondelet than any coal yet found, and so far as opened, give a product of most excellent quality. With all of these sources, the prospect of a larger and cheaper supply of fuel is certainly quite flattering.

The coke works, which were organized more than a year ago, have not yet gotten into successful operation, but have demonstrated enough to render it certain that a good quality of coke can be made from our common coals by grinding and washing the coal before coking, and it cannot now be long before the process will be in successful operation. When these several conditions are fulfilled our supremacy as an iron market is established. But the production of cheap iron here is not entirely dependent upon cheap fuel. The cost of transportation is too great and the delays in transfer very harassing; for instance, the Iron Mountain Railroad Company charge $8 per car of iron from Carondelet to St. Louis (a distance of 6 miles), although the iron is both loaded and unloaded without cost to the railroad, and cars are sometimes as long as 7 days coming this distance. Such an expense and delay in making deliveries when the haul is only 6 miles cannot be sustained upon any principle of reciprocal interest, and demands the enlightened attention of the managers of the Iron Mountain railroad. Next to this is the delay and cost of transfer. In many cases cars loaded with fuel have been detained 5 weeks at East St. Louis when the furnaces were needing it, and still longer delays in making shipments of metal by transfer from the furnaces to East St. Louis were experienced. With the furnaces at Carondelet in full blast they handle 1,300 tons of ore, fuel, metal, and rails per day; but so far the railroad appliances for handling this large business seem unnecessarily crude. These difficulties have suggested a road from East St. Louis to Carondelet to be built as a toll road for the use of all roads, and will be a great assistance to an interest now suffering so much from the hindrance indicated. This road will be only about 7 miles in length and should be built in the next 60 days, as there is but little grading to be done. The Missouri Pacific propose also to put in a branch to Carondelet. This will give the furnaces the advantage of competing ores and greater varieties of mixtures. With the various roads that are now proposing to build to Carondelet, a bridge is also necessary, and a charter and organization are completed, and it will likely be well under way before the close of 1872. When these improvements are consummated furnaces will be out of the woods; until then the tariff they pay at home will more than counterbalance the protection that their congressional champion, Mr. Kelley, can possibly get.

With a confident belief that all these hindrances are soon to be removed, we shall leave the furnaces to see how the other iron interests have prospered. With them it is not difficult to guess the result, as with a cheaper and better qualitied iron than could be had anywhere else, they have been unusually successful, and they should be encouraged in such degree as to induce a large increase in the erection of manufactories in the various departments. All of them have run to their full capacity, and some have turned out more work than ever before, and are even finding a large market for their goods on the Pacific coast and in the North and East, when they have heretofore been supplied entirely from the Eastern markets. The Rail Fastening Company, which started in 1871, has been unusually successful, and intend making large additions to their works. The wire works have also been prosperous, and these will be largely increased during the coming year. The Vulcan Works made a very successful start with their new mills. At the first effort, the machinery turned as easily as if it had been in use for years, and produced a remarkably handsome rail of excellent quality. These works are a credit to the energy and enterprise of the builders, and to be in the centre of a country where so many railroads are being built and to be built, it is gratifying to know that we have a mill capable of turning out every day rails for 1½ miles of road. This is certainly a large capacity, but, taking account of the roads west of the Mississippi river that are already built, being built, and projected, and it is plain that we are in want of several such establishments.

Of all the manufacturing interests that would do well here, large steel works, both for merchant steel and steel railroad bars, seem to promise best, as it is now practically demonstrated that Missouri iron is well adapted to steel purposes. This is proven in that several hundred tons of it have been tried at the Bessemer steel works at Troy, N. Y., and first-class steel rails made from it with entire satisfaction. The iron that can be used for this is difficult to obtain in this country, and in Europe commands a much higher price than the ordinary pig iron. Here, where it sells at $5 per ton less than the common irons of Pennsylvania and New York, seems to us the place for such works, and with the market in this condition, with the furnaces running at ½ their capacity, with sales during the year of say, 25,000 tons to go up the Ohio river, it certainly looks as if large steel works could be erected here with good margins for profit, in the centre of a country where there will soon be no limits to its capacity and demands. Before there was a furnace in this State, before the Iron Mountain Railroad was built, before the Iron mountain had its sides disturbed by the pick and torn by the blast, a metallurgist of some note predicted that the Mississippi valley would become the great iron manufacturing centre of America. His prediction is gaining strength with each succeeding year, and in less time than many imagine the proof of it will be visible.

Last year the production of all the furnaces was: of stone coal furnaces, 36,200 tons, of charcoal furnaces, 33,303; total, 69,503 tons. This year we are unable to get full statistics in time, but estimate it as slightly larger. The low prices of pig iron for the first 8 months of the year was a dam-

per on production, rating, as it did, at about $31 per ton, but for 4 months prices have ranged from $38 to $39, and better prospects are ahead. The following are the statistics of the products, etc., of such furnaces and mills as we have obtained:

STONE COAL FURNACES.—Germania Iron Works, Carondelet, opened May 1st, produced 850 tons pig iron, and 75 tons bloom.

Lewis Iron Company, two furnaces; productions 1871, 13,500 tons pig iron; 1870, 6,000 tons.

South St. Louis Iron Company; production 1871, 10,300—a balance of 3,000 tons is on hand awaiting shipment, mostly to points on the Ohio river.

Vulcan (and Kingsland) Iron Works. This mill was idle several months, owing to low prices of iron, "induced by reduction of tariff." We have therefore only obtained their capacity, etc: Capital of company, $2,000,000; number of hands employed, 800; capacity of furnaces per year, 30,600 tons; capacity of rail mill per year; 40,000 tons; wages paid per month about $40,000.

CHARCOAL FURNACES.—Irondale furnace, February 1 to October 13, 1871, hot blast, 4,909 tons; December 1 to December 31, cold blast, 322 tons; mainly sold in Pittsburgh.

Pilot Knob Iron Company. Production of 1871, pig iron, 6,275 tons, of which 1,520 tons were sold to Pittsburgh, and 2,670 tons to Wheeling; the remainder here

IRON MOUNTAIN COMPANY.—The following will give the operations of the Iron Mountain Company for 1871:

Iron ore raised and shipped from the mountain: ore raised, 169,796 tons; ore shipped, 156,310 tons; ore delivered to furnaces at Carondelet, 56,571½ tons; ore shipped by river to Ohio and Grand Tower, 92,530 tons; ore shipped by rail, 35,951 tons; pig iron produced, 6,759 tons.

Pig iron shipped by river, 6,014 tons; by rail, 1,410 tons; disposed of in the city, 4,000 tons.

Of the above ore shipments by rail, 19,389 tons went to Indiana; 900 tons went to Chattanooga.

Balance shipments by rail went to Pittsburgh, Cincinnati, Wheeling, and other points.

Iron ore on landing January 1, 1860, 100,000 tons; January 1, 1871, 80,000 tons.

The Scotia Iron Company was not in operation the entire year, but made 5,525 tons, of which 2,000 tons were of cold blast. The sales have generally been made in St. Louis.

The Helmbacher Forge and Rolling Mills (stone coal) commenced operations about the last of 1870, and its productions have been as follows:

	Tons.
Bar iron produced	2,120
Railroad car axles 11,300 or	1,650
Sundry forgings	150
Total production	3,920
Pig metal consumed	2,300
Scrap iron	2,350
Coal	15,000
Men employed	180
Wages paid during the year	$101,500

The largest shaft ever made in the West, was made in November by A. Helmbacher, 20 ft. in length and weiguing 13,000 lbs.—*St. Louis Times.*

RAILWAY NOTES.

SPEED OF PASSENGER TRAINS IN ENGLAND.—From a London contemporary we get the statement below of the speed of those lines which make the best time in that country. On this side of the Atlantic many exaggerated notions prevail with regard to the velocity with which trains sometimes move; but cautious persons will admit that some of the lines go quite fast enough:

"What speed are we going at?" is a question one often hears asked in railway carriages, and it might very easily be answered correctly. Most people, however, have a general sort of impression that express trains always travel at the rate of 60 miles per hour, and when late and making up time very much faster. But let us see what the speed of some of our fastest trains really is. The Limited and Irish mails run from Euston to Rugby, 82½ miles, in 2 hours, or at rather less than 42 miles per hour. From Croydon to Brighton is done at under 43 miles per hour, and the speed of the West of England express from Waterloo Bridge is about the same. The continental trains from Charing Cross and Cannon street to Dover also do about 43 miles an hour. Two trains, however, are rather faster. The Manchester express goes from Kentish town to Leicester, a distance of 97¼ miles in 2 hours and 8 min., the speed being 46 miles an hour; and the Scotch express from King's Cross at 8.10 reaches Peterboro', 76¼ miles in 1 hour 37 min., travelling at over 47 miles an hour. Of course, in such long runs the velocity will vary considerably, as the train ascends or descends inclines, or is passing stations and junctions where high speed would be dangerous. A few miles may be done at 60 or 70 miles an hour, and some at 20 or 30, but the average speed is usually about 45.

However, it is very easy to test these statements experimentally. Most people have watches with seconds hands, and every railway has a post at every ¼ mile. Now 900 divided by the number of seconds which elapse between the moments of passing any two posts of ¼ mile apart will give the speed of the train in miles per hour.—*American Railway Times.*

CURVED SMOKE-STACK.—The "Boston Transcript" says, for the benefit of railroad travelers, that the desideratum so long sought for by inventors, namely, a practical spark and dust arrester, after repeated experiments and failures, has at last been brought to what may be termed perfection by a gentleman of Massachusetts. The invention is simply a curved smoke stack, in nearly the shape of a "horn of plenty," attached as ordinary smoke stacks are, the mouth running backward toward the centre of the locomotive. Within, near the enlargement at the upper curve, is placed a wire screen at an angle of about 45 deg. with the direction of the smoke, and the usual screen is placed over the immediate outlet.

Just below the first screen a perforated steam stack is run horizontally through the smoke stack connected with the boiler by a valve-pipe under the control of the engine-driver. As the refuse matter from the furnace passes through the stack, it is moistened by the fine spray ejected from the perforations, thus deadening the particles and increasing their weight. Striking at the inclined angle named above against the first screen, they are prevented from passing through, and fall to the under curve of the stack, whence, through the

natural motion of the engine, they are directed by a tube to beneath the boiler, and thrown upon the track in a moist and consequently harmless state.

This invention has been on trial upon the Fitchburg railroad during the past three weeks with sufficient success to warrant the inventor in pushing his plans to perfection. The advantage of the curved stack is not only in the prevention of dust and cinders upon the train, but to avoid the damage by fires along the track, which have been the cause of so much expense to railway companies. This latter object is completely attained, and that without any apparent loss of power. It was at first supposed that the draft would be so seriously checked by the new stack as to counterbalance the other advantages, but experiments have shown that such is not the case, and that steam is made equally as well as with the ordinary stack.

CONDITION OF THE PACIFIC RAILWAYS.—The Secretary of the Interior, in his annual report, gives the following interesting exhibit of the affairs of the three Pacific railways:

UNION PACIFIC.

Subscriptions to capital stock	$36,783,000
Subscriptions paid in	36,672,300
Receipts of all kinds	7,362.015
Cost of road, including fixtures	112,703,618
Total indebtedness	74.653,512
Due the United States	27,236,612

CENTRAL PACIFIC.

Subscriptions to capital stock	$59,644.000
Subscriptions paid up	54,283,190
Receipts	7,326.327
Expenses	3,745.766
Net earnings	3.580,560
Total indebtedness	71,430,732
Due to the United States	27,851,000

NORTHERN PACIFIC.

Stock subscribed	$100,000,000
Stock paid up	2,241,600
Expenses to June 30, 1871	4,936,871
Indebtedness	9,085,764

—*Railway Register.*

A NOVEL METHOD OF OPERATING A RAILROAD BY TELEGRAPH.—The Denver (Col.) Correspondent of the "New York Tribune," in a recent communication, gives the following interesting details of a novel method adopted for running of trains on the Denver and Rio Grande Railroad by telegraph:

"It is hoped that accidents by the narrow gauge will be few, because with the ordinary brake a train can be brought to a stand as quickly as other trains can be by the improved patent brakes. The centre of gravity in the small cars is 10 per cent. lower than in the larger ones, hence the cars are least likely to overturn, and the whole weight of the train being less, collisions must be less violent. The Denver and Rio Grande line is conducted under a new method. The engineer alone has charge of running the train. The conductor is an agent, and he is also a telegraphic operator. He carries a telegraphic apparatus with him, and stations are attached to telegraph poles—being little more than shelves—and the agent communicates orders to the engineer. The poles are numbered in mile sections, from 1 to 26, and the miles are marked on the poles as if milestones. By this means the engineer, who keeps record of the condiiton of the track, can report to the master mechanic at the end of the trip, or sooner, any defect within 100 ft., by naming the number of the pole and section where work is needed. The master mechanic has charge of maintenance of way, and, having reports by telegraph, as above stated, he at once directs where work is to be done It is reported that this road is to be extended to the old city of Mexico, and that offers of money have been made from the owners of rich mines in that remote region. Thus we may expect that this road, now just commenced, will be extended to the capital of the Montezumas—a distance of over 1,800 miles from Denver. It is to be said, in addition, that an extension of the narrow gauge northward has been surveyed, running through our town, to connect with the Union Pacific at Pine Bluff."—*The Telegrapher.*

RAILROAD BRIDGE AT ST. JOSEPH, MO.—About 200 men are now employed on this bridge. The caisson near the western shore is being sunk, the work is going on night and day without intermission.

THE GOODALE STEAM BRAKE COMPANY are putting their brakes upon the trains of the Ohio and Mississippi and Iron Mountain railroads. These roads have investigated the matter thoroughly, and have decided that the Goodale patent possesses many points of superiority over any other.

ATLANTIC AND PACIFIC.—Arrangements have been completed for ironing and equipping an important branch of this road, running from Pierce City west hrough Carthage, Jasper county, into Kansas.

THE ST. LOUIS, LAWRENCE AND DENVER.—It is announced that this road, running from Pleasant Hill, on the Missouri Pacific, to Lawrence, on the Kansas Pacific, will be completed about the 15th inst.

ENGINEERING STRUCTURES.

KANSAS CITY BRIDGE.*—Civil engineers, bridge builders, and all persons connected with public works, are under great obligations to the authors of this valuable monograph upon the first bridge constructed across the Missouri river, for the admirably complete and clear manner in which they have described the various processes conducted by them. Their modesty has prevented their taking that credit to themselves which is their just due. The difficulties which presented themselves were overcome one by one as they occurred, in such a quiet and successful manner, that very few persons who had not watched the progress of the work could believe that there were any unusual difficulties. One who has had good opportunities of knowing and who has seen a few other bridges built, believes that the readers of VAN NOSTRAND'S MAGAZINE will be interested by a brief comparison of the processes used at Kansas

* Kansas City Bridge. By O. CHANUTE, Chief Engineer, and G. MORRISON, Assistant Engineer. New York: D. Van Nostrand, 1870.

City, in sinking deep foundations, with those used and now in use at other places.

The system of sinking cylinders by means of compressed air, through water and semi-fluid strata, was first practised about thirty years ago by French engineers, to get at some coal mines under the bed of the Loire. The air-lock was there invented, and successfully used.

The process was then applied to bridge foundations by sinking two or more tubes to form a pier.

It was soon discovered that there were three objections to this plan.

The first was, that all the material to be raised had to pass through the air-lock. This was a very slow and expensive process. The second objection was, that owing to the small area of the foundation of the tubes, as compared with its height, it was difficult to keep it truly vertical, and still more difficult to replace it, if it once tilted out of position. The third was, that if the soft materials around the tube should be scoured away, it would not be self-supporting, unless sunk into the rock itself.

Two important modifications of the process were introduced almost simultaneously by Mr. Brunel, in his foundation 82 ft. below water at Saltash, and by M. Fleur Saint-Denis, at the bridge between Strasbourg and Kehl, over the Rhine, whose foundations are about 65 ft. deep.

Mr. Brunel used a single tube 35 ft in diameter, instead of several small ones. M. Saint-Denis used 4 caissons firmly bolted together into one before sinking, so as to form a caisson the whole size of his intended pier. This gave sufficient base to insure stability in sinking, and made the pier self-sustaining in case of the sand being scoured away.

This principle of *concentration*, as distinguished from the other plan of separate tubes, was adopted by Mr. Chanute at his bridge, before the success of the St. Louis and Brooklyn foundations had settled the question in its favor. Several eminent engineers had thrown the weight of their professional authority in favor of the tubular plan, and several important bridges had been constructed in that form in this country, although at a great expenditure of time and money.

Mr. Chanute was able to put down his foundations without the use of compressed air, although, in his deepest pier at least, he was prepared to use it if necessary.

The objections to the use of compressed air in tubes were overcome in the system invented by Brunel and Saint-Denis, and since so successfully used at St. Louis and Brooklyn, by the use of the water-shaft.

Brunel confined his compressed air to a chamber in the bottom of his large tube, which communicated with the external air by a pneumatic tube surrounded by an open tube full of water, and fixed to it by radial partitions. The air was forced into the chamber, and the workmen gained access to it through the pneumatic tube, while the materials to be excavated were raised through the outer water tube by buckets and windlass.

At the Kehl bridge, the whole caisson, or rather 4 caissons, formed a compressed air chamber, reached by eight pneumatic tubes, and 4 large water-shafts, used for the same purposes as at Saltash. But in the water-shafts were placed 4 powerful elevator dredges, which raised the materials through them without cessation.

Although this plan has been followed by continental engineers ever since, most English engineers have stuck to the old-fashioned plan of raising all the materials through the air-locks in bags. This tedious process has been followed in the bridge at Omaha, and accounts in a great measure for the length of time which it has taken to build it.

The question as to whether it is proper to use compressed air, or to dredge through open shafts, is one to be determined by the nature of the material to be excavated. In sand rivers, where the dredges feed themselves readily, and there are few sunken logs or *debris* to pass through, the system of dredging is as rapid as manual excavation in compressed air, and much less expensive. But if the material is hard, an air chamber must be used, so that men can attack the river bed with pick and shovel.

Mr. Chanute decided in favor of the dredges, and experience proved the accuracy of his judgment. A pier 70×20 was sunk through 12 ft. of water, and 34½ ft. of sand, to the rock, in 64 days; the time actually employed in dredging and raising being about 600 hours.

The E. pier of the St. Louis bridge was sunk through 40 ft. of water and 63 ft. of sand, to the bed rock in 126 days; but the area to be excavated was four times as great as that of Kansas City Bridge No. 4.

Besides the deep foundations of No. 4, there were others not so deep, but all difficult on account of the rapidity of the current, and the difficulty of maintaining false works.

These piers were put down in different ways, all successfully, and in modes showing great adaptive skill on the part of the engineers.

Old Indians, when they give their boys a gun for the first time, tell them that it is a wicked Manitou, and will kill them if they give it a chance.

This is the only safe rule to be adopted in dealing with one of these large rivers. Never trust it; never give it a chance to hurt you; always expect that it will do the thing you do not want it to do, and then you will finally overcome it.

T. C. C.

THE ST. GOTHARD TUNNEL.—ANOTHER GRAND ENGINEERING WORK.—The pass of St. Gothard was the most frequented of all the routes across the Alps until the commencement of the present century; but, as it was not practicable for vehicles, it was gradually deserted after the construction by Napoleon I., of the road over the Simplon. The lose of the traffic induced the cantons through which the route passed to construct a carriage road quite as good as that on the Simplon. The work was commenced in 1820, and finished in 1832, and it is one of the greatest monuments of engineering skill to be found in Europe. In magnificence of scenery the St. Gothard is superior to all of the passes, unless we except the Stelvio. To the mere pleasure seeker, it will, therefore, be a matter of regret to see this superb road deserted for a hole through the mountain Ever since the Mont Cenis tunnel was projected, the Swiss and Germans have felt that a large share of traffic would be diverted to France. For military and strategic reasons, it was, also, felt that equally good facilities ought to be provided on the other side of Switzerland, and all of the necessary surveys were made many years since; but the jealousy of the French, and the fear of that nation, has prevented the commencement of the work. The moment, however, that France was powerless to pre-

vent, the project was revived, and we now hear that a contract for the construction of the tunnel has been concluded between the Swiss government and a syndicate of German bankers under the protection of the imperial government of Germany. The work will be about twice as long as the Mont Cenis tunnel, and it will be considerably more difficult, as it must pass under several rivers and lakes, and encounter the hardest rocks of the Alps. The summit of the present carriage road is 6,507 ft., but the railroad will pass under peaks varying from 8,750 to 10,900 ft. There is no distinct peak of St. Gothard, but an extensive ridge of elevated ground which bears that name.

Geologists will be greatly interested in the work, as this part of Switzerland abounds in a large variety of choice minerals, and some important questions may be solved by the projected work. The total cost is estimated at $37,000,000. Of this amount the company will raise $20,000,000, leaving the balance to be raised by assessment upon the cantons and countries immediately interested in the project. There is a general belief among engineers that the work will cost much more money than the above estimate, but, as rich governments stand as security, there seems to be little doubt that the undertaking will be pushed to final completion. The new road will bring Germany and Italy into closer political union, and, in the event of war, give these powers a decided military advantage; but this feature of the undertaking is of small importance in comparison with the enormous traffic that will flow through the tunnel between the nations of the north and the remote inhabitants of Asia. Its principal utility will consist in facilitating trade and travel between Europe and Asia, by way of Italy. The extreme eastern points within its circle of traffic will touch the outstretched hand of our Pacific Railroad, and the commerce of the whole world will be benefited by the completion of the gigantic scheme. It is not many years since the river Danube was the highway for the commerce of the world. The boats moored at the bridge of Ratisbon, far up in the interior of the Continent, were manned by sailors who were the boast of that period, when suddenly, by the discovery of the passage around the Cape of Good Hope, commerce was diverted to new routes, and we have nothing but the ancient bridge and the quaint old storehouses to tell us of the magnificence of the past. The completion of such works as the Suez Canal and the tunnels through the Alps are great illustrations of the triumph of science over all obstacles.

The trade, which, for a time, was diverted to new routes, appears likely to return to its former channels. The Austrian government already have a railroad over the lower Alps, connecting with Trieste and Venice, so that they will profit by the revival of trade in this direction.

It is difficult to anticipate how long it will require to complete the St. Gothard tunnel, but with improved machinery and aided by the experience of Mont Cenis, it can hardly endure twice as long as the last famous undertaking. It is a bold enterprise, well worthy of the age in which we live. —*Iron World and Manufacturer.*

THE ROCK ISLAND BRIDGE.—The Rock Island bridge superstructurists are still devoting their best energies to the construction of the draw, which is one of the heaviest ever put up in the country, being 366 ft long, or 60 ft. longer than the side of a full block in the city. Its construction requires 750 tons of iron, besides the wood work. This vast weight will swing upon a massive turn-table, operated by an engine located on the railroad level of the bridge. This engine and the necessary machinery are being constructed. In case of an accident to the engine, or if for any other reason it cannot be operated, the draw can be turned by a set of hydraulic jack-screws, provided for the purpose. Some of the iron sections of the turn-table are of such weight that one of them is a full load for a car. Work upon the third span from the Iowa shore will be commenced in about two weeks. The false-work for the fourth and last span will not in all probability be commenced upon until the river is frozen over at the point.—*Exchange.*

ST. JOSEPH'S BRIDGE.—More than 3 000 cubic yards of stone have been delivered on the Kansas shore for this new bridge, and it is arriving at the rate of 13 car-loads daily. Temporary dikes have been constructed on this shore which have turned the lower water channel from it. A permanent dike further down will be half a mile long and will be protected with rip-rap. It is now 550 ft. long and 60 ft. wide. The contractors, the Detroit Bridge and Iron Company, commenced sinking the western pier on the 4th inst. It will reach rock 45 ft. below the surface. Col. E. D. Mason, the accomplished engineer who had charge of the construction of the Hannibal Bridge, is supervising the structure.

NEW BRIDGE AT CARONDELET.—It is stated that a large amount of stock has been subscribed, and that the proposed bridge will be commenced early in the coming season. It will be of iron, and adapted for railways, with crossing for wagons, etc. below. Its entire length, including trestle-work, will be 2,174 ft. Its estimated cost is $2,000,000.

LAKE CHAMPLAIN BRIDGE.—The trestle work of the new railroad bridge across Lake Champlain is 1,800 ft. long, and it is intended, at intervals of 100 ft. to build piers, 30 ft. square at the bottom, and 12 ft. by 30 at the top. The boat to be used as a drawbridge is 300 ft. long, 30 wide, and 12 high, contains 250,000 ft. of lumber, weighs about 300 tons, and is expected to draw 2 ft. of water. 800 piles, length 80 ft., were required to build the trestle work, from either shore to the draw; this latter is to be connected to a pier by hinges, and swings back and forth like a door, by means of a chain.

BOOK NOTICES.

NOTE-BOOK ON PRACTICAL SOLID OR DESCRIPTIVE GEOMETRY, CONTAINING PROBLEMS WITH HELP FOR SOLUTIONS. By J. H. EDGAR, M. A., and G. S Pritchard. London and New York: Macmillan & Co., 1871.

When our Civil and Military Engineering Examinations are daily making larger demands for geometrical proficiency a new and exceedingly lucid Note-book on Descriptive Geometry comes well-timed. Though much has been done to expand this collateral offshoot of geometrical science since M. Monge, of the Ecole Polytechnique, first start-

ed it, the co-ordinative characteristic of a science has hitherto been wanting; it has contained, doubtlessly, all the abstract principles of orthographic projection, but principles, to be available, must be interdependent and derivative. Messrs. Edgar and Pritchard have felt this deficiency, and have done much to remove it. Their book, unlike the majority of cheap han -books, is neither "patchy nor scrappy," but a continuous and coherent whole. "Elementary Explanations, Definitions, and Theorems" come first, followed by 28 problems on "the Straight Line and Plane;" to these succeed Solids, first singly, and then in "Groups and Combinations." In like logical order we next have "Solids with the inclinations of the plane of one face, and of one edge or line in that face given," and then "Solids with the inclinations of two adjacent edges given," and, lastly, in this category, "Solids with the inclinations of two adjacent faces given" So far we have the principles of projection in a much more perfectly co-ordinated arrangement than we have hitherto found them in, and we must say that the mere act of mentally assimilating this interdependence of principles would be wholesome discipline, even if it did not, as it unquestionably does, facilitate each successive step in progress, and, most of all, conduce to an integral entertainment of the subject. Again, as naturally derivable from the consideration of the inclined faces of solids, we arrive at "Sections by oblique planes," and "Developments," or the spreading out in one plane of the adjacent faces of such solids; and, finally, the development of curved surfaces. "Miscellaneous Problems" now have place, and amongst them we notice one from the "Science Examinations" of last year. The sequence of the 4 next chapters is judicious. "Tangent Planes," "Intersections of Solids with plane surfaces," "Intersections of Solids with curved surfaces," "Spherical Triangles." A short chapter on Isometric Projection (quite as long as it deserves) ends the work, the authors of which we rejoice to find (in these days of "result-seeking") much more desirous of results actual than results visible, and accordingly, foregoing a somewhat too popular profusion of diagrams, which, while it undoubtedly facilitates the bare apprehension of subject-matter, by no means enforces that comprehension of the subject which attends upon the act of accomplishing a mental diagram for ourselves. In this expression of their conviction the authors, we observe, are at one with Mr. Binns, who, with the same sincerity, and for like reason, resisted the systematic use of models in the teaching of "mechanical drawing."

Messrs. Edgar and Pritchard have produced an inexpensive, but a well-digested, comprehensive, lucid, and typographically attractive *vade mecum*. —*Nature*.

INORGANIC CHEMISTRY. By GEORGE WILSON, M D. Revised and enlarged by H. G. MADAN. London and Edinburgh: W. & R. Chambers. For sale by Van Nostrand.

The earlier edition of this excellent work was widely used in this country, because in addition to an attractive style, the author afforded a means of comparing the two methods of notation in all important formulas. This latter advantage is not retained by the new editor; but the work has lost nothing in clearness of exposition or excellence of method by the revision.

MARVELS OF POND LIFE. By HENRY J. SLACK, F. G. S. London: Groombridge & Sons. For sale by Van Nostrand.

This is a delightful book for amateur microscopists, as it affords instructions in regard to collecting living objects for the microscope every month in the year.

The author is an enthusiastic lover of the study of the lower organisms, and his style is calculated to awaken a desire to work in this department of natural history.

PETIT TRAITE DE PHYSIQUE. Par M. JAMIN. Paris: Gauthier Villars. For sale by Van Nostrand.

This is a convenient hand-book of 700 pages, containing a complete compend of physics. The illustrations are numerous and excellent, and serve to elucidate the most advanced state of experimental science. The widespread celebrity of the author's larger work will guarantee a demand for this later though smaller treatise.

A COMPLETE COURSE OF PROBLEMS IN PRACTICAL PLANE GEOMETRY. By J. W. PALLISER. London: Simpkin & Marshall.

Mr. Palliser is a master and lecturer on geometrical drawing at the Leeds School of Art and Science, and the work is specially designed as a text-book for students in art and science schools and night classes connected with the Science and Art Department. It contains constructive and descriptive problems in plane geometry, to prepare candidates for any of the Government examinations in this subject; and is to be followed by one on "Solid Geometry."

PICTURESQUE ARCHITECTURAL STUDIES. By WILLIAM YOUNG, Architect. Parts 2 and 3. London: Spon.

The title "Picturesque Architectural Studies," scarcely describes the work, which consists, so far as it goes, of designs for lodges, cottages, and so forth, by the author, some of which have been carried out. Mr. Young in the present parts includes plans and elevations for cottage hospitals. A design for a vicarage-house is not without merit. Mr. Young has a free fancy and a freer pencil. The sketchy style of drawing adopted leads to want of precision.

FLINT. A PAPER READ BEFORE THE GEOLOGISTS' ASSOCIATION. By M. H. JOHNSON, F. G. S. Printed for private circulation. Bacon, Printer, Lewes.

This paper was read in June last. It treats of the deposit of flint or silex in chalk, and suggests a theory to explain how sponges, etc., produce the flint nodules in chalk mud. The author proposes to utilize such a process in the arts and manufactures, by coating perishable surfaces with silex while embedded in calcareous or argillaceous mud, with the help of soluble silicates and decomposing organic matters. An engraving is given of a specimen of orbicular silica, the flints having been deposited in concentric circles, the markings of which, curiously resemble the concentric circles on the rocks of Northumberland and Argyleshire, as well as the "spectacle ornament," as it has been called, upon the standing stones in Scotland. Still, we are far from suggesting anything like identity. The concentric circled markings on rocks, on the

stones at New Grange, on the Scottish and other stones, are associated with other markings more obviously carved, but the coincidence is curious.

MISCELLANEOUS.

M. Pleischl, of Vienna, claims to have discovered a vitreous enamel for metals which combines the properties of durability, freedom from noxious ingredients, and malleability by contact with the substances to which it is applied, and he has lately exhibited some specimens of enamel work which have elicited high commendation. Among these were plates of copper, the coating of which bore exposure to heat and resisted the action of acids, possessing also the important property of allowing the plate to be bent to an acute angle without either scaling or cracking. This enamel is free from lead or zinc. It is is not liable, therefore, to the serious objection to lead glazes, of contaminating liquids contained in the vessels coated with it with poisonous salts. It also bears very rough treatment, endures a hard scratching with a knife without losing its polish or showing any trace of the implement, and, though heated to any degree, even to redness, it continues to be perfectly sound, the only precaution necessary to be taken being not to cool it suddenly by contact with water. It is harder than glass, which it scratches, and is not even scratched or marred in the slightest degree by the most thorough scouring with sand.

The great bridge at St. Louis is progressing rapidly. The concrete or foundation for the last pier, a small one on the Illinois side of the river, has been laid and the bridge company will have no further use of the air pumps, voltaic armor, etc. The masonry, of which there will be 103,000 cubic yards, is about two-thirds completed, and the superstructure has already been commenced. The cast-iron plates at the piers have been placed and prepared for the reception of the steel tubes forming the spans. It will be completed in about a year from now.

Lubrication of Steam Engines.—It has been a long time the practice with horologists, to use graphite as a reducer of friction, in even the most delicate pieces of mechanism. In blowing engines also, if the gearing is copper, graphite is the only lubrication used. These facts led M. Thoma, C E., of Memmingen, to try a mixture of graphite (prepared by decantation) and hog's lard, first in the stuffing box of a pumping engine, and subsequently upon a steam engine. The result was very satisfactory; the only care requisite was to keep up the quantity of graphite in the mixture, as otherwise it it becomes too fluid. The next experiment was made with a paste of graphite and water. The result was equally good; the slight escape of steam into the stuffing box was sufficient to keep the graphite moist, and the lubrication seemed quite perfect, although there was no fatty matter present.—*Railway Times.*

From China to England.—While we can hardly feel the enthusiasm of our contemporary (the San Francisco "Bulletin") in the comments we quote, we still feel that they are in a great degree true, or at the least worthy of notice. It says:

"Our English cousins are further astonished at the rapidity with which we move in this country; and at the fact that a passenger who left this city by the overland railway on the 2d ult., and took passage at New York on the Wisconsin, arrived at Liverpool on the 19th, making the trip in 17 days, they are so surprised that they telegraph it back as an 'unprecedented' occurrence. It would seem that the British public are just wakening to knowledge of the fact that Yankee enterprise has furnished the shortest and most expeditious route between Liverpool and not only San Francisco, but China and Japan, for the time made by this passenger did not beat that which may be made by anybody who leaves this city in time to connect with steamer at New York. In fact, nearly as rapid time has been made by freight from this city to Liverpool. A consignment of raw silk, valued at $68,000 gold, which arrived here per the "American" on July 15th, was started overland on the 17th, arrived at New York on the 27th, less than an hour after was on board an outward bound steamer, and arrived in Liverpool August 7th, making the transit from San Francisco in only 20 days, and from Yokohama in but 46 days, two days delay being occasioned by transfer and passing the custom house at this city.

"When express trains are run as doubtless they will be, to accommodate Liverpool freights overland, the time can be shortened 3 days, making the distance from Yokohama to Liverpool in 43 days, as against 73 days by the English steamers *via* the Suez canal. The result cannot but tell on the commerce of this port, which might be increased immensely, especially if the dock system were reformed so as to reduce to a minimum the expenses of vessels discharging cargoes here."—*Railway Review.*

Steam Boiler Explosions.—The following record of boiler explosions in the United States during 1871, is copied from the Report of the Hartford Boiler Insurance Company.

	Explosions.	Killed.	Wounded.
Saw and planing mills	30	57	46
Steamboats and tugs	22	289	137
Manufactories of various kinds	22	13	19
R. R locomotives	13	21	38
Flour and grist mills	5	15	5
Oil wells	3	3	1
Brass foundries	2	1	3
Rotary bleachers	2	..	..
City Water Works	1	..	..
U. S. Navy Yard	1	.	.
Iron Foundry	1	2	3
Miscellaneous	3	3	9
	105	404	261

Experiments to Determine the Gravity of the Earth.—Pendulum experiments for determining the gravity of the earth are about to be made in the Mont Cenis Tunnel by Father Secchi, M. Diamiller-Muller and M. R. P Denza. They will be made first in a lateral chamber about the centre of the tunnel, and will be afterwards repeated at

the corresponding vertical point on the mountain, the difference of level being about 1,600 metres. In addition to these observations, they propose to determine the earth's magnetism, and the temperature of the strata to which they can obtain access. By preliminary observations, they have ascertained that the movement of the trains will not to any serious extent interfere with the precision of the observations. Telegraphic wires will be laid down for the purpose of chronographic registration, and the observing chamber will be ventilated by special air conduits.—*Comptes Rendus.*

NEW FILTERING PROCESS.—The waterworks of Dunkerque, completed in 1870, include the application of a filtering process, arranged by M. Pauwels, the city engineer, in charge of the works. The filtering system of Dunkerque is analogous to the self-cleaning filters established at Paisley by Mr. Thom, and in which the duty is equal to 27,500 gals. per 24 hours, with an area of 7,100 sq. ft.

The total thickness of M. Pauwels' filter is only 26 in., arranged as follows:

in.			in.
5 124	Formation	Bricks laid on edge	
1 194		Tiles set in Portland cement	18 118
5.900		Calais gravel	
5 900		Culm	
7.882		Filtering bed of fine sand	7.882
26.000		Total thickness in inches.	26 000

The 5.9 in. of culm in the formation is laid in 3 beds, in which the fragments decrease in size from the bottom to the top. This material has given good results, allowing the water to flow through, and being absolutely impermeable to the grains of sand which form the upper bed. The gravel, on the contrary, allows the sand to pass gradually, gets choked rapidly, and reduces the useful effect of the filter. The duty of the filter reaches the proportion of 8 cube metres to 1 sq. metre per 12 hours.

It is well known that in a certain number of localities the results of filtration have not been entirely satisfactory. M. Pauwels believes that he has overcome all difficulties by the combination he has adopted, that is, by the use of the beds of coal-dust under the layer of sand.

TESTING STEEL BY THE MICROSCOPE.—John Schott, an eminent chemist, asserts that different qualities of iron and steel can readily be distinguished by means of the microscope. The crystals of iron are double pyramids, in which the proportion of the axes to the bases varies with the quality. The smallness of the crystals and the height of the pyramids composing each element are in proportion to the quality and density of the metal, and these are to be detected also in the fineness of the surface. As carbon diminishes in steel, the pyramids have less height. In pig iron and the lower qualities of hard steel, the crystals approach more closely the cubic form.

Forged iron has its pyramids flattened and reduced to superposed parallel leaves, whose structure constitutes what is called the nerve of the steel. The best quality of steel has all its crystals disposed in parallel lines, each crystal filling the interstices between the angles of those adjoining. These crystals have their axes in the direction of the percussion they undergo in the working. Practically good steel, examined under the microscope, has the appearance of large groups of beautiful crystals, similar to points of needles, all parallel.

VEGETABLE PARCHMENT.—The common method of preparing this exceedingly useful material requires much care and experience on the part of the operator, and only gives satisfactory results when the strength of the sulphuric acid and length of the process is accurately apportioned to the substance and texture of the unsized paper to be dipped. Mr. Colin Campbell has made a modification of this process, which promises many advantages. Before treating the paper with sulphuric acid, he dips it in a strong solution of alum, and dries it thoroughly. When paper thus prepared is passed through concentrated sulphuric acid, it is converted into parchment paper just as before, but the presence of the alum prevents the action of the acid from being so rapid as before, and therefore renders the whole operation much more manageable. Paper which has been printed on can also be converted into vegetable parchment if treated in this way. The author also proposes to make parchment paper in endless lengths, by connecting the alum and sulphuric acid bath with the paper machine.—*Dingler Polytech. Journal*, Band CC., p. 509.

DEEP SEA EXPLORATIONS.—An important intimation was made at the meeting of the British Association, by Dr. Carpenter, to the effect that he had communicated with the Chancellor of the Exchequer and the First Lord of the Admiralty on the subject of securing assistance from Government for carrying out a deep-sea exploration. Mr. Lowe had replied that he was favorable to the scheme; and Mr. Goschen had written a letter, which was read by Dr. Carpenter, in which it was stated that the First Lord of the Admiralty had consulted with his colleagues, and both he and they would give favorable consideration to a general proposal for carrying on exploring operations in the Atlantic, Pacific, Southern, and Indian Oceans.—*English Mechanic.*

THE Boatford Bridge, Langholm, N. B., which was only lately finished, fell while about 200 people were upon it. A photographer was in the act of photographing the structure when the catastrophe took place, through one of the chains breaking. The bridge was an iron and wire suspension one of 175 ft span, and had a very handsome appearance. One or two persons on the bridge received slight injuries.

THE Spanish cinnabar mine, at Almaden, is one of the last places where one would expect to find one of Boulton & Watt's original engines, but it appears that one was erected there in 1799, and has been at work ever since.

SUBMARINE TELEGRAPH IN ASIA.—Telegraphic communication is now open between Shanghai (China) and Nagasaki (Japan).

WEST INDIAN TELEGRAPHS.—The West Indian and Panama Telegraph Company (Limited) have just received a telegram announcing the successful laying of the section of their cable between Demerara and Trinidad.